BEFORE THE
PUBLIC SERVICE COMMISSION

Application of Highland Wind Farm, LLC,
for a Certificate of Public Convenience and Necessity
to construct a 102.5 MW Wind Electric Generation Facility
and Associated Electric Facilities, to be Located in
the Towns of Forest and Cylon, St. Croix County, Wisconsin

Docket No.: 2535-CE-100

AFFIDAVIT OF JEREMY B. LYON IN SUPPORT OF REQUEST FOR CONFIDENTIAL HANDLING

STATE OF WISCONSIN)
) ss.
COUNTY OF DANE)

Jeremy B. Lyon, being first duly sworn, attests as follows:

1. I am an attorney with Oliveira Law Group representing the Town of Forest, an intervenor party in this docket. Our office is located at 22 East Mifflin Street, Madison, WI 53703.

2. This affidavit is made pursuant to section PSC 2.12, Wisconsin Administrative Code, in support of a request for confidential handling of the Town of Forest's Comments in Response to the Commission's Order to Reopen, Notice and Request for Comments.

3. This filing includes HIPPA-protected information in the form of unredacted versions of comments submitted by individuals attesting to health conditions, and are therefore exempt from disclosure under chapter 19, Wisconsin Statutes.

Jeremy B. Lyon

Subscribed and sworn to before me
This 15th day of April, 2015.
Sarah E Howe
Notary Public
Dane County, Wisconsin
My Commission Expires: 7/13/19

SARAH E HOWE
NOTARY PUBLIC
STATE OF WISCONSIN

OFFICIAL FILING
BEFORE THE
PUBLIC SERVICE COMMISSION

Application of Highland Wind Farm, LLC, for a Certificate of Public Convenience and Necessity to construct a 102.5 MW Wind Electric Generation Facility and Associated Electric Facilities, to be Located in the Towns of Forest and Cylon, St. Croix County, Wisconsin	Docket No.: 2535-CE-100

TOWN OF FOREST'S COMMENTS IN RESPONSE TO THE COMMISSION'S ORDER TO REOPEN, NOTICE AND REQUEST FOR COMMENTS

INTRODUCTION

On March 15, 2016, the Commission issued its Order to Reopen, Notice and Request for Comments, reopening for the limited purpose of addressing the issues remanded by the Decision and Order in *Town of Forest v. Pub. Serv. Comm'n of Wis.*, No. 14-CV-18 (Wis. Cir. Ct. St. Croix Cnty. Aug. 27, 2015). These issues include:

1. The Commission's intention to modify its Final Decision on Reopening to remove the pre-established 95 percent compliance standard and address any complaints concerning alleged noncompliance with the noise standards, based on the specific factual situation, at the time any noncompliance is alleged;
2. To allow the parties to state why the six identified potentially sensitive residences, and other potentially sensitive residences already identified in Ex.-Forest-Junker-20, should be considered for lower noise requirements than is provided for in Wis. Admin. Code § PSC 128.14(3), so that the Commission can decide whether to include lower noise requirements for either these six or any additional residences;

3. To take official notice under Wis. Stat. § 227.45 of specified governmental reports of peer-reviewed studies, relating to whether any identified health concerns are affected by wind electric generation facilities, and provide the parties an opportunity, as required by Wis. Stat. § 227.45, to rebut or present countervailing evidence.

The Town of Forest submits the following comments in accordance with the Commission's Order to Reopen, Notice and Request for Comments. We respectfully request that the Commission hold a hearing on any compliance standards, by percentage or otherwise, rather than relying solely on the regulatory complaint process. We further ask that the Commission extend the lower noise requirements to all seventeen households established as sensitive residences to ensure the health and safety of the residences of the hosting community. Finally, we request the Commission consider additional medical, scientific, and governmental literature describing the deleterious health effects of proximity to wind electric generation facilities, to ensure the protection of all non-participating residences.

While the record in this matter is already voluminous, and while we appreciate the Commission's time, patience, and thoughtful decisions, the Town of Forest must remain opposed to the CPCN for this project as currently designed. We understand that holding hearings as we request will potentially prolong this matter further, but we ask that the record—to include the standards by which any future complaints will be evaluated—be fully established in order to protect the residents of the Town. We also ask that the Commission remember that it was the Applicant, and not the Town, who decided to design a project using up to 44 of the largest wind turbines in the state, interspersed throughout the Town, without the consent of the municipality that would be compelled to host it. The Town regrets the prolonged dispute in this matter, but not as much as it regrets the situation in which it finds itself.

I. THE COMMISSION SHOULD HOLD A HEARING TO ESTABLISH COMPLIANCE STANDARDS PRIOR TO FACILITY CONSTRUCTION, AS A COMPLIANCE STANDARD WILL INEVITABLY BE APPLIED DURING THE COMPLAINT PROCESS.

The Commission's rules establish an absolute limit on noise attributable to wind energy systems operations under normal operating conditions. "[A]n owner shall operate the wind energy system so that the noise attributable to the wind energy system does not exceed 50 dBA during daytime hours and 45 dBA during nighttime hours." Wis. Admin. Code § PSC 128.14(3). The *Wind Siting Council Final Recommendations to the Public Service Commission* further clarify that, "[f]or all system size categories, the noise attributable to the system *should never be allowed* to exceed 45 dBA at night or 50 dBA during the day, as measured at the outside wall of any nonparticipating residence or occupied community building." (emphasis added). The Commission's Final Decision of March 15, 2013 also determined that the Applicant must comply with these noise limits.

Applicant's design, however, cannot adhere to these limits, as Clean WI's expert David Hessler indicated, and as the Commission recognized when it first considered the 95% compliance standard. There is little debate that Applicant's project, as designed, will inevitably suffer from spikes of noise during its normal operating conditions that will exceed the noise limits. Consequently, if we apply the strict adherence of the noise limits required in the rule, Applicant's project facially fails to meet its design burden. Applicant would ask this Commission to view the Town's reliance on the absolute noise limit as an unrealistic and draconian requirement interfering with the development of alternative energies. The Town, however, notes that these requirements would be considerably easier to meet had the Applicant not decided to push the boundaries by building massive turbines peppered throughout residential areas. This is a design flaw of their own making.

The Commission now asks for comments on whether any percentage-compliance standard should be discarded, and the regulatory complaint process employed instead to rectify the deficiencies post-construction. A review of that complaint process, which follows, should assist in detailing the fundamental shortcomings of this approach. If noise spikes are inevitable for some percentage of time, these same parties will be compelled to appear before the Commission again, arguing the same positions and asking for a noise compliance standard for a project that is ultimately nonviable, but after hundreds of millions of dollars have been expended to build that nonviable project. All parties would benefit from a compliance standard *now*, before the sunk costs in this matter become astronomical.

The complaint process to be used post-construction is found in Wis. Admin. Code § PSC 128.40, which outlines the process. For illustration, we will discuss a hypothetical—and, according to the parties, inevitable—complaint. "A complaint [by an aggrieved person for noise violations] shall be made first to the owner of the wind energy system pursuant to a complaint resolution process developed by the owner." *Id.* at § 128.40(b). Here, a resident of the Town of Forest living in a non-participating home complains of excess dBA to the Applicant. We do not yet possess a complaint resolution process developed by the Applicant, but for purposes of the argument, we will assume that the aggrieved resident is not satisfied with the outcome.

Now the Town of Forest, an intervening party to this matter, enters the process. "A complainant may petition the political subdivision for review of a complaint that is not resolved within 45 days of the day the owner receives the original complaint." *Id*. at § 128.40(c). The Town may issue a decision, subject to review under Wis. Stat. § 66.0401(5), curtailing or mitigating the Applicant to comply with the strict enforcement of the noise limits. Wis. Stat. § 128.40(d).

An imposition or enforcement of a restriction on a wind energy system by a political subdivision may be appealed to the Public Service Commission. Wis. Stat. § 66.0401(5)(a). This may include an intermediate step in which the Applicant appeals first to the political subdivision, but for purposes of illustration, let us imagine that the Applicant and the Town of Forest have dramatically divergent views about the project, and assume that the municipal review does not leave Applicant satisfied.

The Commission must now apply the noise limits, under some compliance standard, of Wis. Admin. Code § 128.14(3) to the complaint and the project. "If the commission determines that the political subdivision's decision or enforcement action does not comply with the rules it promulgates under s. 196.378(4g) or is otherwise unreasonable, the political subdivision's decision shall be superseded by the commission's decision and the commission may order an appropriate remedy." Wis. Stat. § 66.0401(5)(d). As the PSC's rules currently include strict enforcement of the noise limits, without any compliance standard to deviate from the absolute limit, Applicant's project would be permanently curtailed.

A project design that would require permanent curtailment in order to operate is a project that has failed to meet its design burdens to receive a CPCN in the first place. Additionally, if the Town of Forest's curtailment decision involves rendering one turbine permanently inoperable, for example, then the project in reality is only 43 turbines, with a 44th expensive but dormant turbine built ultimately for the sole purpose of bringing the name-plate energy production of the project out of the Town's jurisdiction and into the Commission's. A design that includes one turbine operating consistently at over 45 dBA is a design that violates the current regulations, and a design that requires rendering that turbine permanently inoperable in order to continue operations of the other 43 is a design that does not meet the jurisdictional requirements of the Commission.

However, as the Commission has already indicated that it may consider some degree of deviation from the standard to be acceptable under normal operating conditions, it is possible that the Commission may consider applying a compliance standard to supersede the Town of Forest's decision. To illustrate, this dispute would have the Applicant on one side and the Town of Forest on the other, each asking the Commission to employ divergent compliance standards for the project. This is exactly where the parties are today. The largest distinction, however, is that our hypothetical scenario would occur only after the Applicant has expended a considerable sum building the project, whereas addressing the matter now would save all parties from irrecoverable harm, including sunk costs, potential health effects, and diminished property value.

It is also worth noting that either party, if aggrieved by the Commission's decision, can further appeal that decision to the St. Croix County Circuit Court. Wis. Stat. § 66.0401(5)(f). This is the same Court that remanded this matter to the Commission "for the purpose of providing proper notice and hearing on the issue of adopting a percentage compliance standard" to resolve this ambiguity. *Town of Forest* at 113. In essence, the complaint process looks practically identical to the current procedural posture of the parties, so removing the language regarding percentage compliance standards has accomplished very little.

In summary, the Commission will eventually be compelled to address a compliance standard for wind energy noise emissions. Without a deviation from the absolute noise limits, Applicant's plan facially fails to meet the requirements for a CPCN. With a deviation, a CPCN may be appropriate as regards the noise limits, but it is unclear how that deviation will be evaluated under any compliance standard. Ultimately, the adoption of some form of compliance standard is inevitable for this project. The Town of Forest suggests that it would benefit all parties to establish this standard now, rather than after construction is completed and the unavoidable noise violations begin. We respectfully ask the Commission for a hearing on the adoption of a compliance standard so that the parties may supplement the record with expert testimony regarding the appropriate application of any compliance standard.

II. THE COMMISSION SHOULD EXPAND THE PROTECTION FOR IDENTIFIED SENSITIVE RESIDENCES TO COVER ALL SEVENTEEN RESIDENCES; ALTERNATIVELY, THE COMMISSION SHOULD HOLD A CONTESTED CASE HEARING TO DETERMINE WHICH RESIDENCES SHOULD BE CLASSIFIED AS SENSITIVE.

The Commission has reopened the record to allow parties to state whether other potentially-sensitive residences identified in Ex.-Forest-Junker-20 should also be considered for lower noise requirements during night-time operation. The Commission may be considering removing the “sensitive” classification entirely and applying the 50-45 dBA across every non-participating residence. We respectfully request that the Commission expand the 40 dBA night-time restriction to all seventeen identified residences, as there is no appropriate method of distinguishing between their individual circumstances without a more thorough examination as provided by a contested case. In the alternative, and whether or not the Commission intends to adjudicate that the protection interests conferred on the six residents should be removed, a contested case hearing is appropriate to determine which households or individual residents should be subject to reduced noise standards.

While the Commission may modify any order at any time and for any reason, it is important to note that the Court in this matter remanded for a very specific purpose: “the matter is reopened solely for the purpose of allowing the parties to state why other sensitive residences, already identified, should be considered and the Commission can then decide if others, already identified, *should be included with the original six residences*." *Town of Forest* at 114 (emphasis added). The remand did not include language that would allow for the removal of the privileges already conferred on the six residences. While a new order from the Commission might potentially determine that no residences will receive special consideration, the Court clearly envisioned that a contested case hearing should be held on this matter. Furthermore, those six residences received a privilege in the Final Order, and that portion of the Order was not nullified or suspended by the Court. To remove the six residents in a future order would be an injury against privileges already conferred, which would itself merit a contested case. And if one contested case for six residents must be held, the Commission should proceed to hear all seventeen for the purpose of completing the record and complying with the terms of the Court's order.

There is no suitable method, without a contested case, of evaluating the residents in Ex.-Forest-Junker-20 and determining which have health conditions warranting protections. The seventeen households identified report an array of medical issues, each of which may be exacerbated by the effects of wind turbines, but each in different ways. Many of these residents have multiple of these symptoms, and these symptom combinations may further interact in unique ways. Many of the medical conditions are easily applicable here: two residents are diagnosed with sleep apnea and three with various sleep disorders, for example. As the Wind Siting Report 2014 discusses sleep deprivation being reported by between 40-66% of the effected population when wind turbines operate at or above 45 dBA, these individuals are likely especially vulnerable to noise exceedances around their residences during the night.

Infrasound and low-frequency noise also have potential negative health effects and can exacerbate certain conditions. Schomer et al 2015, which is submitted and referenced in the third section of this Comment, highlights symptoms of motion sickness, vertigo, undue fatigue, headaches, and nausea, and their study considers wind turbine infrasound and LFN as the likely cause. The Salt and Lichtenhan 2014 article cited in the Wind Report 2015 , and also submitted here, highlights the effects of LFN and infrasound on physical changes in the ear, and highlights how dizziness and nausea—especially in Meniere's disease—are exacerbated in the vicinity of wind turbines. Salt and Lichtenhan further explain how infrasound, LFN, and traditional dBA operating on the human ear concurrently caused ear lesions and reduced hearing ability. While this would affect all residents subjected to a turbine operation running continuously at 50/45 dBA, it would have additional ramifications for the four household members reporting pre-existing hearing loss.

The seventeen households also contain eight reports of individuals suffering from migraines and other headaches, two of vertigo, two of motion sickness, and one of general dizziness. These are all symptoms that would be exacerbated by proximity to turbines operating at the legal limit, as Schomer et al's article explains. The traditional "A" weighting of noise does not account for all impacts of noise on the human body, and as medical science continues to identify the specific harms caused by proximity to turbines, the Commission should certainly afford extra consideration to the household members reporting symptoms that we do know are exacerbated by infrasound and LFN.

One household reports an individual with seizures, while a second specifically reports epilepsy. These residents are especially vulnerable to the effects of shadow flicker, as described by Harding et al 2008, submitted here. Another three residents report heart arrhythmias and high blood pressure, and while we are not suggesting that turbines impact the heart and blood, we certainly are suggesting that stress impacts the heart. The “Wind Siting Report 2014,” of which this Commission is taking official notice, borrows from the WHO to define “annoyance” as “a feeling of resentment, displeasure, discomfort, dissatisfaction, or offence which occurs when noise interferes with someone’s thoughts, feelings, or daily activities.” “Wind Siting Report 2014” at 2. We suggest that “stress,” defined by the WHO as “the reaction people may have when presented with demands and pressures that are not matched to their knowledge or abilities and which challenge their ability to cope,” and “annoyance” should be related terms here. As the “Wind Siting Report 2014” highlights that between 40-66% of people, depending on the survey, reported undue annoyance when turbines were operating at or above 45 dBA, this high level of stress will disproportionately impact those with heart conditions.

These are a sizable list of dramatically varied health conditions, each of which can be exacerbated in some way by the proximity of wind turbines. The Commission could approach this considerable array of health conditions in many different ways, to include attempting to remove special protections altogether for every resident identified. The best response, however, would be to hold a contested case hearing for all seventeen households, to allow each family to present its specific health conditions and to give the Commission the benefit of expert testimony on whether these conditions are exacerbated by proximity to turbines or whether a night-time noise reduction would mitigate their health concerns. We currently do not have enough information to provide a well-reasoned acceptance or denial to each household’s request, but a contested case hearing would resolve this. The six residents currently conferred privileges by the Final Decision and Order have a substantial interest in maintaining those privileges; consequently, an effort to remove their protections would also result in a contested case hearing.

We respectfully suggest that the Commission's best course of action is to build a record on these households' medical issues and tailor elements of the project that endanger their health. Consequently, this Commission should expand the protections to all seventeen households, or it should hear, in a contested case, the evidence for each identified household.

III. THE COMMISSION SHOULD TAKE NOTICE OF THE MINORITY REPORT OF THE WIND SITING COUNCIL AND THE EMERGING SCIENTIFIC LITERATURE DESCRIBING THE CAUSAL EFFECTS OF TURBINE PROXIMITY TO NEGATIVE HEALTH OUTCOMES.

The Commission has taken official notice of two documents regarding whether any identified health concerns are affected by wind electric generation facilities, and reopens for parties to provide countervailing evidence. "The Wisconsin Wind Siting Council Wind Turbine Siting-Health Review and Wind Siting Policy Update" ("Wind Siting Report 2014") and "Review of Studies and Literature Relating to Wind Turbines and Human Health" ("Wind Report 2015") both review scientific and government publications to assess the medical issues surrounding proximity to wind turbines. Both determine that there is an increase in complaints at residences subjected to over 40 dBA, and this project will certainly exceed 40 dBA for multiple residences. "Wind Siting Report 2014" at 8-9; "Wind Report 2015" at 8. Furthermore, while eight of the fourteen Council members recognized that proximity to turbines can cause annoyance but were not yet convinced that medical science had established causality, it is important to note that the other six members appended a Minority Report stating that "[t]he overwhelming empirical evidence from the peer-reviewed literature" established that proximity to turbines was highly correlated with negative health implications. "Wind Siting Minority Report 2014" at 10.

First, the Council majority did identify some health concerns linked with wind turbines, although the "limited empirical research on wind-health issues" compelled them to avoid making any definitive statements regarding causality. *Id.* at 3. While the Minority disagrees with that conclusion, we should begin by highlighting the medical concerns that both sides do agree upon: for at least some of the population, proximity to wind turbines causes annoyance and sleep deprivation. “Wind Siting Report 2014” at 3-4; “Wind Report 2015” at 8. These symptoms are exacerbated, and the size of the effected population increases, with noise output above 40 dBA. “Wind Siting Report 2014” at 8-9; “Wind Report 2015” at 8. The National Association of Regulatory Utility Commissioners (NARUC) commissioned a report, to which the Wind Siting Report 2014 cites, which consequently recommends “a 40 dB(A) noise level as an ideal design goal with a 45 dB(A) regulatory limit at non-participating residences.” “Wind Siting Report 2014” at 19.

The literature relied upon by the Council demonstrates a disturbing growth in sleep deprivation at higher levels of noise, especially when it exceeds 45 dBA. For example, the Pederson 2011 study highlighted that only 4% of the population reported sleep deprivation when the turbines operated at around 30 dBA. “Wind Siting Report 2014” at 8. This number skyrockets to 66% of the study population when the turbines operate around 45 dBA. *Id*. This dramatic increase of effects was mirrored in the Bakker and Janssen studies. The Council majority and minority agree that sleep impacts health, and this relationship should not be in dispute. However, when the majority indicated that only a small percentage of the population would be effected by sleep deprivation because of proximity to wind turbines, they were basing this conclusion off of much smaller turbines, not interspersed through residential areas, operating with much lower noise emissions.

As the Commission takes official notice of the Council majority’s conclusions, it should also take notice of the noise conditions the Council relied upon to draw those conclusions. At 30 dBA, the Council could very easily be right when concluding "that the majority of individuals living near wind energy systems do not experience adverse health effects or reduced well-being." "Wind Siting Report 2014" at 12. The literature places an implicit caveat on this conclusion, however: at 45 dBA, the majority of individuals living near wind energy systems *do* report considerable sleep deprivation and annoyance. This is an entirely different conclusion drawn from the same literature, and the only difference is the level of noise output. As this project will constantly be operating at the 50/45 dBA limit, with exceedances that the parties state will be inevitable, the Council majority would have significant difficulty applying their conclusion here. The Pederson, Bakker, and Jannssen research relied upon by the Council consistently agrees: at 45 dBA, it is not a small percentage of the population effected, it is a significant majority. These were not the articles that the Council discounted as having too small a sample size or questionable results; these were the primary sources relied upon in reaching their conclusion.

The Minority Report, which was drafted by six of the fourteen Council members, is not so hesitant to show how sleep deprivation and annoyance dramatically impacts human health. "Minority Report 2014" at 5-6. The minority states what the majority merely implies: when turbines produce over 40 dBA at non-participating residences, the health effects are substantially exacerbated. *Id*. They are also not so quick to discount the research on infrasound and low-frequency noise and its impacts on human health. The "Wind Report 2015" rectifies this shortcoming by citing some literature regarding the impacts of infrasound and LFN, specifically the Salt and Lichtenhan article, stating that it "may prove useful for future research on health effects or experts working on sound measurement protocols." "Wind Report 2015" at 8. The Salt and Lichtenhan article is appended to this Comment, as we believe that it is useful not merely in the future, but now. We highlight for the Commission page 25 of the article, which further describes the specific impacts of infrasound and LFN on certain sensitive groups.

We also submit the Schomer et al article published in 2015, which describes the possible effects of motion sickness attributable to proximity to wind turbines, especially large turbines. This article uses the Shirley wind project as its subject of study, and given the similarities between the Shirley project and this project, its findings should be especially applicable here. While the article only advances a theory rather than demonstrating causation, it is simply more evidence that the Commission should approach large projects in residential areas with great caution.

In summary, while the Commission takes notice of the Council's conclusions, it should also take notice of the caveats in that conclusion. This project will not be operating at 30 dBA. It will push the absolute limits provided by the Commission's rules, with "inevitable" exceedances. The turbines are not isolated in a rural or industrial area, they are interspersed among non-participating residences. Every article cited by the Council, when it addresses noises at or exceeding 45 dBA, advises caution. The Council's reports state only that wind energy *can* be safe, which is of course true. It does not state that *this* project is safe, and in fact, the cited articles show that it is not. A project that creates conditions where a staggering two-thirds of effected residents suffer from sleep deprivation and annoyance is simply not a viable project in terms of public health. Again, this is a problem of Applicant's own making; this could have been designed in a safer manner, but it was not. It is not the Town of Forest that decided to design some of the largest turbines ever constructed in the state interspersed amongst non-participating residences.

IV. CONCLUSION

The Commission could amend its Final Order and Decision in many different ways, but the best course of action is to proceed to a contested case hearing on these issues. A contested case will be practically inevitable as regards the compliance standard, and it is better for all parties if this critical standard is established prior to construction. If the Commission is not inclined to extend the sensitive 40 dBA protections to all seventeen households, then a contested case hearing would allow the Commission to hear evidence on exactly which households should be protected. A contested case would certainly be necessary in the event that the Commission wishes to consider removing the protections already granted to the six residents in the Final Order, as administrative agencies may easily grant privileges but may not so easily rescind them.

As a contested case regarding noise standards would involve expert testimony on the health issues caused by louder emissions, no additional action would be required regarding the "Wind Siting Report 2014" and the "Wind Report 2015." Furthermore, these publications already highlight the dangers of developing a project that will consistently push the absolute limits of noise emissions within residential areas, so regardless of the majority's conclusion, the articles speak for themselves. This project has fundamental design flaws which cannot be rehabilitated, in a town of residents that do not wish to host such a project. Consequently, if the Commission does not decide to deny the CPCN, a contested case hearing is the appropriate to determine exactly how the project will be monitored and who will be protected.

Respectfully submitted this 15th day of April, 2016.

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TOWN OF FOREST

MEDICAL AND SCIENTIFIC ARTICLES

1. **"How Does Wind Turbine Noise Affect People?" Salt and Litchtenhan, *Acoustics Today*, Winter 2014.**
2. **"Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them," Harding et al, *Epilepsia*, 2008.**
3. **"A theory to explain some physiological effects of the infrasonic emissions at some wind farm sites," Schomer et al, *Journal of the Acoustical Society of America*, March 2015.**

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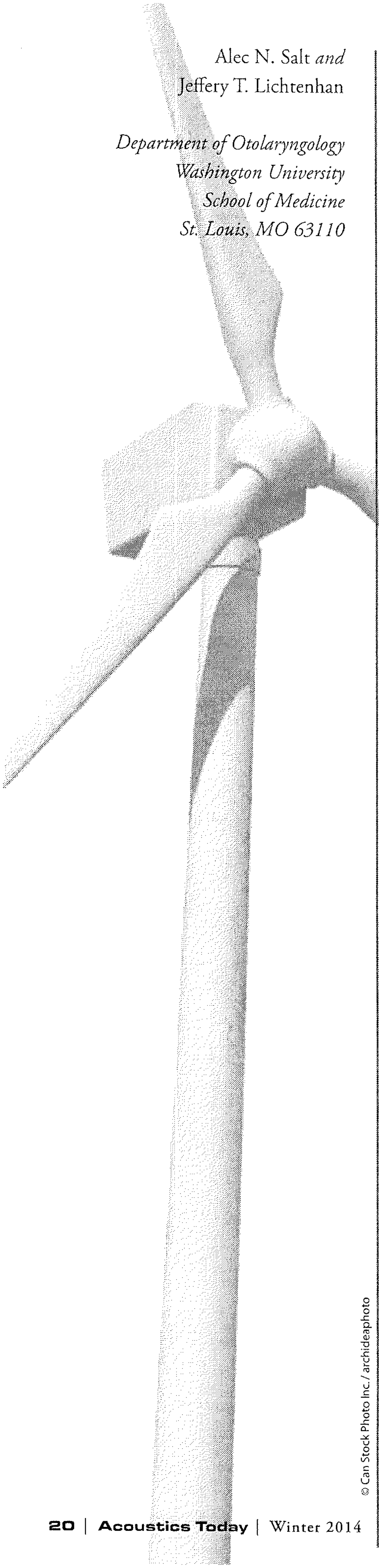

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How Does Wind Turbine Noise Affect People?

The many ways by which unheard infrasound and low-frequency sound from wind turbines could distress people living nearby are described.

Introduction

Recent articles in *Acoustics Today* have reviewed a number of difficult issues concerning wind turbine noise and how it can affect people living nearby (Leventhall 2013, Schomer 2013; Timmerman 2013). Here we present potential mechanisms by which effects could occur.

The essence of the current debate is that on one hand you have the well-funded wind industry **1.** advocating that infrasound be ignored because the measured levels are below the threshold of human hearing, allowing noise levels to be adequately documented through A-weighted sound measurements, **2.** dismissing the possibility that any variants of wind turbine syndrome exist (Pierpont 2009) even when physicians (e.g., Steven D. Rauch, M.D. at Harvard Medical School) cannot otherwise explain some patients' symptoms, and, **3.** arguing that it is unnecessary to separate wind turbines and homes based on prevailing sound levels.

On the other hand you have many people who claim to be so distressed by the effects of wind-turbine noise that they cannot tolerate living in their homes. Some move away, either at financial loss or bought-out by the turbine operators. Others live with the discomfort, often requiring medical therapies to deal with their symptoms. Some, even members of the same family, may be unaffected. Below is a description of the disturbance experienced by a woman in Europe we received a few weeks ago as part of an unsolicited e-mail.

"From the moment that the turbines began working I experienced vertigo-like symptoms on an ongoing basis. In many respects, what I am experiencing now is actually worse than the 'dizziness' I have previously experienced, as the associated nausea is much more intense. For me the pulsating, humming, noise that the turbines emit is the predominant sound that I hear and that really seems to a ect me.

While the Chief Scientist [the person who came to take sound measurements in her house] undertaking the measurement informed me that he was aware of the low frequency hum the turbines produced (he lives close to a wind farm himself and had recorded the humming noise levels indoors in his own home) he advised that I could tune this noise out and that any adverse symptoms I was experiencing were simply psychosomatic."

"Almost all measurements of wind turbine noise are A-weighted, making the unjusti ed assumption that hearing is the only way by which infrasound generates physiologic effects."

We asked how she felt when she was away from the wind turbines, to which she replied:

"I did manage to take a vacation towards the end of August and for the two weeks we were away I was perfectly fine."

The goal of our work in this field is to understand whether the physiology of the ear can, or cannot, explain the symptoms people attribute to wind turbine noise. As it is generally the case when debate influences a specific industry's financial interests and legal well-being, the scientific objectivity of those associated with the industry can be questioned. Liability, damage claims, and large amounts of money can hang in the balance of results from empirical studies. Whether it is a chemical industry blamed for contaminating groundwater with cancer-causing dioxin, the tobacco industry accused of contributing to lung cancer, or athletes of the National Football League (NFL) putatively being susceptible to brain damage, it can be extremely difficult to establish the truth when some have an agenda to protect the status quo. It is only when sufficient scientific evidence is compiled by those not working for the industry that the issue is considered seriously.

Origins of Our Involvement in Infrasound from Wind Turbines

What is the evidence leading us to conclude that unheard infrasounds are part of the wind turbine problem, and how did we become involved in this debate? We are small group of basic and applied scientists, which means that our work addresses fundamental questions on how the ear works in normal and diseased states. While developing paradigms for our studies, we had been using a classic technique called "low-frequency biasing" – measurement of auditory responses to a test sound within the range of audibility, while simultaneously presenting a low-frequency tone (e.g., 4.8 to 50 Hz) to displace the sensory organ of the inner ear. Some auditory responses saturate when displaced by the bias tone, which can be used to establish whether the sensory organ is vibrating symmetrically or whether a fluid disturbance has displaced it to one side. A condition called "endolymphatic hydrops," which is found in humans with Ménière's disease, can displace the sensory organ as the space containing the fluid called endolymph swells. In our animal experiments we initially used 20 to 50 Hz bias tones, but for many reasons, and in large part based on a study in which we found that the ear responded down to 1 Hz (Salt and DeMott, 1999), we started using the lowest frequency our hardware could generate, 4.8 Hz, a frequency considered to be infrasound. Over the course of hundreds of experiments, we have found numerous biasing effects with 4.8 Hz tones at levels of 80 to 90 dB SPL (i.e., -13 to -3 dBA). We also found that the ear became about 20 dB more sensitive to infrasonic bias tones when the fluid spaces in the cochlear apex were partially occluded, as occurs with endolymphatic hydrops.

In late 2009, the first author received a report of a woman with Ménière's disease whose symptoms – primarily dizziness and nausea – were severely exacerbated when she was in the vicinity of wind turbines. From our animal data, we knew this woman was likely hypersensitive to very low-frequency sounds. Our subsequent review of the literature on wind-turbine noise revealed two aspects that were absolutely astounding:

1. Almost all measurements of wind turbine noise are A-weighted, making the unjustified assumption that hearing is the only way by which infrasound generates physiologic effects. The few studies that reported un-weighted measurements of wind-turbine noise, or recalculated spectra by removing the A-weighting from published A-weighted spectra, clearly demonstrated increasing energy towards low frequencies with highest energy levels in the infrasound region. We were surprised that objective full-frequency measurements showed that wind turbines generate infrasound at levels capable of stimulating the ear in various ways. Under such circumstances, A-weighting measurements of turbine noise would be highly misleading.

2. Literature and websites from the wind industry often contained strong statements that wind turbine infrasound was of no significance. This view was largely based on publications by Leventhall (2006; 2007). Wind turbine noise was described as comparable to rustling leaves, flowing streams, air-conditioned offices or refrigerators heard from the next room. If wind turbine noise really was comparable to such sources then complaints would not be expected. But the turbines sounds are only comparable to these sources if the ultra-low frequencies emitted by the turbines are ignored through A-weighting. Stations that monitor infrasound or low frequency seismic (vibrational) noise for other purposes (for the detection of explosions, meteors, volcanic activity, atmospheric activity, etc.) are well-aware that low frequency sounds emanating from distant wind farms, or coupling to the ground as vibrations, can influence their measurements. The UK, Ministry of Defense has opposed wind turbines cited within 50 km of the Eskdalemuir Seismic Array. We have seen no reports of the Ministry opposing the presence of refrigerators in the region, suggesting they appreciate that sounds emitted from wind turbines and refrigerators are quite different. It was thus quite astounding to see the vast majority of wind turbine noise measurements excluding the low frequency noise content. Given the knowledge that the ear responds to low frequency sounds and infrasound, we knew that comparisons with benign sources were invalid and the logic to A-weight sound measurements was deeply flawed scientifically.

The Ear's Response to Infrasound

Experimental measurements show robust electrical responses from the cochlea in response to infrasound (Salt and DeMott, 1999; Salt and Lichtenhan 2013). This finding was initially difficult to reconcile with measures showing that hearing was notably insensitive to such sounds but the explanation became clear from now-classic physiological studies of the ear showing that the two types of sensory cell in the cochlea had very different mechanical properties (Cheatham and Dallos 2001).

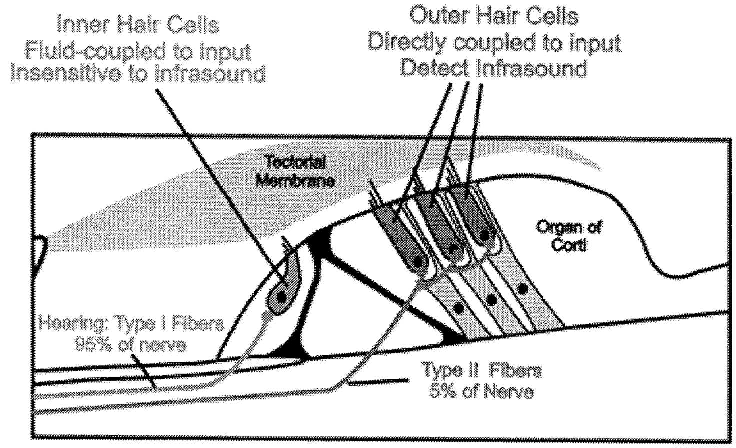


Figure 1 : *e sensory organ of the cochlea, showing inner and outer hair cell and neural anatomy.*

The auditory portion of the inner ear, the cochlea, has two types of sensory cell. The inner hair cells (IHC; shown green in *Figure 1*) are innervated by type I afferent nerve fibers that mediate hearing. The stereocilia (sensory hairs) of the IHCs are free-floating and do not contact the overlying gelatinous tectorial membrane (shown gray). They are mechanically displaced by fluid movements in the space below the membrane. As their input is fluid-coupled to the vibrations of the sensory organ they exhibit "velocity sensitive" responses. As the velocity of motions decreases for lower-frequency sounds, their fluid-coupled input renders the IHC insensitive to very low-frequency sounds. The other type of sensory cell, the outer hair cells (OHC; shown red in *Figure 1*) are innervated by type II afferent nerve fibers that are not as well understood as type I fibers and probably do not mediate conscious hearing per se. In contrast to the IHC, the stereocilia of the OHCs are inserted into the tectorial membrane. This direct mechanical coupling gives them "displacement sensitive" properties, meaning they respond well to low–frequency sounds and infrasound. The electrical responses of the ear we had been recording and studying originate from the sensitive OHCs. From this understanding we conclude that very low frequency sounds and infrasound, at levels well below those that are heard, readily stimulate the cochlea. Low frequency sounds and infrasound from wind turbines can therefore stimulate the ear at levels well below those that are heard.

The million-dollar question is whether the effects of wind turbine infrasound stimulation stay confined to the ear and have no other influence on the person or animal. At present, the stance of wind industry and its acoustician advisors is that there are no consequences to long-term low-frequency and infrasonic stimulation. This is not based on studies showing that long-term stimulation to low-level infrasound has no influence on humans or animals. No such studies have ever been performed. Their narrow perspective shows a remarkable lack of understanding of the sophistication of biological systems and is almost certainly incorrect. As we consider below, there are many physiologic mechanisms by which long-term infrasound stimulation of the cochlea could have effects.

One important aspect of wind turbine noise that is relevant to its physiological consequences is that the duration of exposure can be extremely long, 24 hours a day and lasting for days or longer, depending on prevailing wind conditions. This is considerably different from most industrial noise where 8 hour exposures are typically considered, interspersed by prolonged periods of quiet (i.e., quiet for 16 hours per day plus all weekends). There are numerous studies of exposures to higher level infrasound for periods of a few hours, but to date there have been no systematic studies of exposure to infrasound for a prolonged period. The degree of low-frequency cochlear stimulation generated by wind turbine noise is remarkably difficult to assess, due to the almost exclusive reporting of A-weighted sound level measurements. It certainly cannot be assumed that cochlear stimulation is negligible because A-weighted level measurements are low. For example, with 5 Hz stimulation cochlear responses are generated at -30 dBA and stimulation is sufficient to cause responses to saturate (indicating the transducer is being driven to its limit) at approximately 20 dBA (Salt and Lichtenhan, 2012; Salt et al., 2013). We have also shown that 125 Hz low-pass filtered noise at just 45 dBA produces larger responses than wide band noise with the same low-frequency content presented at 90 dBA (Salt and Lichtenhan 2012). We conclude that low frequency regions of the ear will be moderately to strongly stimulated for prolonged periods by wind turbine noise. There are a number of plausible mechanisms by which the stimulation could have effects:

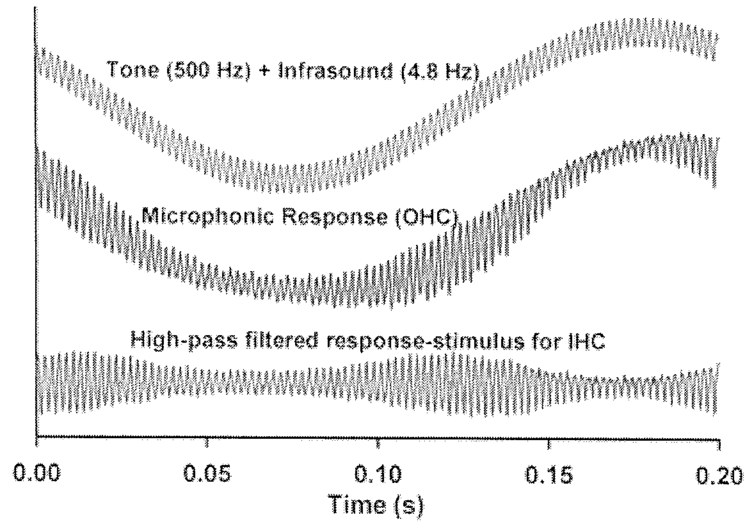


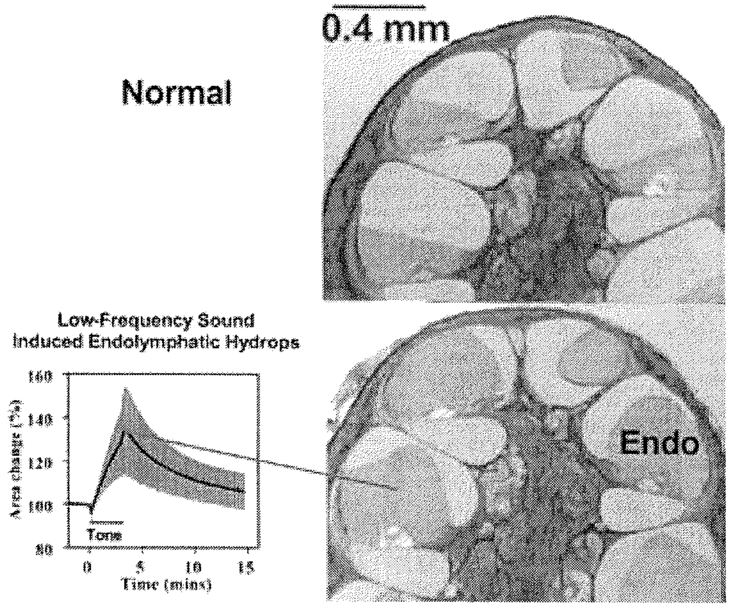
Figure 2 : *Demonstration of biologically-generated amplitude modulation to a non-modulated stimulus consisting of an audible tone at 500 Hz tone summed with an infrasonic tone at 4.8 Hz. e cochlear microphonic response, which is generated by the OHC, includes low and high frequency components. e IHC detect only the high frequency component, which is amplitude modulated at twice the infrasound frequency for the stimuli in this example.*

1. Amplitude Modulation: Low-Frequency Biasing of Audible Sounds

Modulation of the biological mechano-electric transducer of the inner ear by infrasound is completely different from the amplitude modulation of audible sounds that can be measured with a sound level meter near wind turbines under some conditions. This can be demonstrated in low-frequency biasing paradigms in which a low-frequency tone and higher-frequency audible tone are presented simultaneously to a subject.

OHCs respond to both low- and high-frequency components and modulate the high-frequency components by either saturation of the mechano-electric transducer or by cyclically changing the mechanical amplification of high frequencies. IHCs, being insensitive to the low-frequency tone, see a high pass-filtered representation of the OHC response – an amplitude modulated version of the audible probe tone, as shown in *Figure 2.* As hearing is mediated through the IHCs that receive approximately 90-95% of afferent innervation of the auditory nerve, the subject hears the higher-frequency probe tone varying in amplitude, or loudness. A similar biasing influence on cochlear responses evoked by low-level tone pips was explained by the low-frequency bias tone changing OHC-based cochlear amplifier gain (Lichtenhan 2012). This same study also showed that the low frequency, apical regions of the ear were most sensitive to low-frequency biasing. Studies like this raise the possibility that the amplitude modulation of sounds, which people living near wind turbines report

Figure 3 : *Brief exposures to low-frequency tones cause endolymphatic hydrops in animals (Salt, 2004) and tinnitus and acoustic emission changes consistent with endolymphatic hydrops in humans (Drexel et al, 2013). e anatomic pictures at the right show the di erence between the normal (upper) and hydropic (lower) cochleae e endolymphatic space (shown blue) is enlarged in the hydropic cochlea, generated surgically in this case.*



as being so highly annoying, may not be easily explained by measurements with an A-weighted sound level meter. Rather, the low-frequency and infrasound levels need to be considered as contributing to the perceived phenomenon. Subjectively, the perceived fluctuation from an amplitude modulated sound and from a low-frequency biased sound are identical even though their mechanisms of generation are completely different. For the subject, the summed effects of both types of amplitude modulation will contribute to their perception of modulation. Acousticians therefore need to be aware that the degree of modulation perceived by humans and animals living near wind turbines may exceed that detected by a sound level meter.

2. Endolymphatic Hydrops Induced by Low Frequency Tones

As mentioned above, endolymphatic hydrops is a swelling of the innermost, membrane bound fluid compartment of the inner ear. Low-frequency tones presented at moderate to moderately-intense levels for just 1.5 to 3 minutes can induce hydrops *(Figure 3)*, tinnitus (ringing in the ears) and changes in auditory potentials and acoustic emissions that are physiological hallmarks of endolymphatic hydrops (Salt, 2004, Drexl et al. 2013).

Unlike the hearing loss caused by loud sounds, the symptoms resulting from endolymphatic hydrops are not permanent and can disappear, or at least fluctuate, as the degree of hydrops changes. Return to quiet *(as in Figure 3)* or relocation away from the low-frequency noise environment allow the hydrops, and the symptoms of hydrops, to resolve. This which would be consistent with the woman's description of her symptoms given earlier. As hydrops is a mechanical swelling of the membrane-bound endolymphatic space, it affects the most distensible regions first – known to be the cochlear apex and vestibular sacculus. Patients with saccular disturbances typically experience a sensation of subjective vertigo, which would be accompanied by unsteadiness and nausea. As we mentioned above, an ear that has developed endolymphatic hydrops becomes >20 dB more sensitive to infrasound because the helicotrema becomes partially obstructed *(Salt et al.* induced hydrops that causes the ear to be more sensitive to low frequencies – has to be considered. To date, all studies of low-frequency tone-induced hydrops have used very short duration (1-2 min) exposures. In humans, this is partly due to ethical concerns about the potential long-term consequences of more prolonged exposures (Drexel et al., 2013). Endolymphatic hydrops induced by prolonged exposures to moderate levels of low-frequency sound therefore remains a real possibility.

3. Excitation of Outer Hair Cell Afferent Nerve Pathways

Approximately 5-10% of the afferent nerve fibers (which send signals from the cochlea to the brain - the type II fibers mentioned above) synapse on OHCs. These fibers do not respond well to sounds in the normal acoustic range and they are not considered to be associated with conscious hearing. Excitation of the fibers may generate other percepts, such as feelings of aural fullness or tinnitus. Moreover, it appears that infrasound is the ideal stimulus to excite OHC afferent fibers given what has been learned about these neurons from *in vitro* recordings (Weisz et al, 2012; Lichtenhan and Salt, 2013). *In vivo* excitation of OHC afferents has yet to be attempted with infrasound, but comparable fibers in birds have been shown to be highly sensitive to infrasound (Schermuly and Klinke, 1990). OHC afferents innervate cells of the cochlear nucleus that have a role in selective attention and alerting, which may explain the sleep disturbances that some people living

> **"The million-dollar question is whether the effects of wind turbine infrasound stimulation stay con ned to the ear and have no other in uence on the person or animal."**

near wind turbines report (Nissenbaum et al. 2012). The likelihood that OHC afferents are involved in the effects of low-frequency noise is further supported by observations that type II innervation is greatest in the low-frequency cochlear regions that are excited most by infrasound (Liberman et al. 1990, Salt et al. 2009).

4. Exacerbation of Noise Induced Hearing Loss

Some years ago we performed experiments to test a hypothesis that infrasound was protective against noise damage (Harding et al. 2007). We reasoned that low-frequency biasing would periodically close the mechano-electric transducer channels of the sensory organ (reducing electrical responses as shown in the biasing studies above), and consequently reduce the amount of time that hair cells were exposed to the damaging overstimulation associated with noise exposure. The experimental study found that just the opposite was true. We found that simultaneous presentation of infrasound and loud noise actually exacerbated noise-induced lesions, as compared to when loud noise was presented without infrasound. Our interpretation was that low-frequency sound produced an intermixing of fluids (endolymph and perilymph) at the sites of hair cell loss resulting in lesions that were larger. A possibility to be considered is therefore that long-term exposure to infrasound from wind turbines could exacerbate presbycusis and noise-induced hearing loss. Because these forms of hearing loss develop and progress slowly over decades, this could be a lurking consequence to human exposures to infrasound that will take years to become apparent.

5. Infrasound Stimulation of the Vestibular Sense Organs

Recent exchanges in this journal between Drs. Leventhall and Schomer concerning the direct stimulation of vestibular receptors by sound at low and infrasonic frequencies deserve comment. Dr. Leventhall asserts that both Drs. Schomer and Pierpont are incorrect in suggesting that wind turbine infrasound could stimulate vestibular receptors, citing work by Todd in which the ear's sensitivity was measured in response to mechanical low-frequency stimulation applied by bone conduction. Leventhall fails to make clear that there are no *studies* reporting either vestibular responses, or the absence of vestibular responses, to acoustically-delivered infrasound. This means that for all his strong assertions, Leventhall cannot refer to any study conclusively demonstrating that vestibular receptors of the ear do *not* respond to infrasound. Numerous studies have reported measurements of saccular and utricular responses to audible sound. Indeed, such measurements are the basis of clinical tests of saccular and utricular function through the VEMP (vestibular-evoked myogenic potentials). Some of these studies have shown that sensitivity to acoustic stimulation initially declines as frequency is lowered. On the other hand, *in vitro* experiments demonstrate that vestibular hair cells are maximally sensitive to infrasonic frequencies (~1 – 10 Hz). Thus, sensitivity to acoustic stimulation may increase as stimulus frequency is lowered into the infrasonic range. Direct *in vivo* vestibular excitation therefore remains a possibility until it has been shown that the saccule and other vestibular receptors specifically do not respond to this stimulation.

Low-frequency tone-induced endolymph hydrops, as discussed above, could increase the amount of saccular stimulation by acoustic input. Hydrops causes the compliant saccular membrane to expand, in many cases to the point where it directly contacts the stapes footplate. This was the basis of the now superseded "tack" procedure for Ménière's disease, in which a sharp prosthesis was implanted in the stapes footplate to perforate the enlarging saccule (Schuknecht et al., 1970). When the saccule is enlarged, vibrations will be applied to endolymph, not perilymph, potentially making acoustic stimulation of the receptor more effective. There may also be certain clinical groups whose vestibular systems are hypersensitive to very low-frequency sound and infrasound stimulation. For example, it is known that patients with superior canal dehiscence syndrome are made dizzy by acoustic stimulation. Subclinical groups with mild or incomplete dehiscence could exist in which vestibular organs are more sensitive to low frequency sounds than the general population.

"For years, they have sheltered behind the mantra, now shown to be false, that has been presented repeatedly in many forms such as 'What you can't hear, can't affect you.'"

6. Potential Protective Therapy Against Infrasound

A commonly-used clinical treatment could potentially solve the problem of clinical sensitivity to infrasound. Tympanostomy tubes are small rubber "grommets" placed in a myringotomy (small incision) in the tympanic membrane (eardrum) to keep the perforation open. They are routinely used in children to treat middle ear disease and have been used successfully to treat cases of Ménière's disease. Placement of tympanostomy tubes is a straightforward office procedure. Although tympanostomy tubes have negligible influence on hearing in speech frequencies, they drastically attenuate sensitivity to low frequency sounds (Voss et al., 2001) by allowing pressure to equilibrate between the ear canal and the middle ear. The effective level of infrasound reaching the inner ear could be reduced by 40 dB or more by this treatment. Tympanostomy tubes are not permanent but typically extrude themselves after a period of months, or can be removed by the physician. No one has ever evaluated whether tympanostomy tubes alleviate the symptoms of those living near wind turbines. From the patient's perspective, this may be preferable to moving out of their homes or using medical treatments for vertigo, nausea, and/or sleep disturbance. The results of such treatment, whether positive, negative, would likely have considerable scientific influence on the wind turbine noise debate.

Conclusions and Concerns

We have described multiple ways in which infrasound and low-frequency sounds could affect the ear and give rise to the symptoms that some people living near wind turbines report. If, in time, the symptoms of those living near the turbines are demonstrated to have a physiological basis, it will become apparent that the years of assertions from the wind industry's acousticians that "what you can't hear can't affect you" or that symptoms are psychosomatic or a nocebo effect was a great injustice. The current highly-polarized situation has arisen because our understanding of the consequences of long-term infrasound stimulation remains at a very primitive level. Based on well-established principles of the physiology of the ear and how it responds to very low-frequency sounds, there is ample justification to take this problem more seriously than it has been to date. There are many important scientific issues that can only be resolved through careful and objective research. Although infrasound generation in the laboratory is technically difficult, some research groups are already in the process of designing the required equipment to perform controlled experiments in humans.

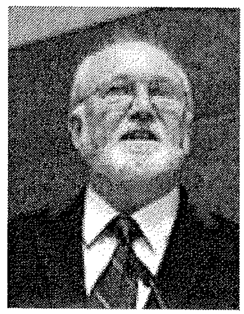
One area of concern is the role that some acousticians and societies of acousticians have played. The primary role of acousticians should be to protect and serve society from negative influences of noise exposure. In the case of wind turbine noise, it appears that many have been failing in that role. For years, they have sheltered behind the mantra, now shown to be false, that has been presented repeatedly in many forms such as "What you can't hear, can't affect you."; "If you cannot hear a sound you cannot perceive it in other ways and it does not affect you."; "Infrasound from wind turbines is below the audible threshold and of no consequence."; "Infrasound is negligible from this type of turbine."; "I can state categorically that there is no significant infrasound from current designs of wind turbines." All of these statements assume that hearing, derived from low-frequency-insensitive IHC responses, is the only mechanism by which low frequency sound can affect the body. We know this assumption is false and blame its origin on a lack of detailed understanding of the physiology of the ear.

Another concern that must be dealt with is the development of wind turbine noise measurements that have clinical relevance. The use of A-weighting must be reassessed as it is based on insensitive, IHC-mediated hearing and grossly misrepresents inner ear stimulation generated by the noise. In the scientific domain, A-weighting sound measurements would be unacceptable when many elements of the ear exhibit a higher sensitivity than hearing. The wind industry should be held to the same high standards. Full-spectrum monitoring, which has been adopted in some reports, is essential.

In the coming years, as we experiment to better understand the effects of prolonged low-frequency sound on humans, it will be possible to reassess the roles played by acousticians and professional groups who partner with the wind industry. Given the present evidence, it seems risky at best to continue the current gamble that infrasound stimulation of the ear stays confined to the ear and has no other effects on the body. For this to be true, all the mechanisms we have outlined (low-frequency-induced amplitude modulation, low frequency sound-induced endolymph volume changes, infrasound stimulation of type II afferent nerves, infrasound exacerbation of noise-induced damage and direct infrasound stimulation of vestibular organs) would have to be insignificant. We know this is highly unlikely and we anticipate novel findings in the coming years that will influence the debate.

From our perspective, based on our knowledge of the physiology of the ear, we agree with the insight of Nancy Timmerman that the time has come to "acknowledge the problem and work to eliminate it".

Biosketches



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BRIEF COMMUNICATION

Wind turbines, flicker, and photosensitive epilepsy: Characterizing the flashing that may precipitate seizures and optimizing guidelines to prevent them

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SUMMARY
Wind turbines are known to produce shadow flicker by interruption of sunlight by the turbine blades. Known parameters of the seizure provoking effect of flicker, i.e., contrast, frequency, mark-space ratio, retinal area stimulated and percentage of visual cortex involved were applied to wind turbine features. The proportion of patients affected by viewing wind turbines expressed as distance in multiples of the hub height of the turbine showed that seizure risk does not decrease significantly until the distance exceeds 100 times the hub height. Since risk does not diminish with viewing distance, flash frequency is therefore the critical factor and should be kept to a maximum of three per second, i.e., sixty revolutions per minute for a three-bladed turbine. On wind farms the shadows cast by one turbine on another should not be viewable by the public if the cumulative flash rate exceeds three per second. Turbine blades should not be reflective.
KEY WORDS: **Photosensitive epilepsy, Flicker, Rotors, Visual discomfort, Wind farms, Wind turbines, Green power.**

The provision of energy from renewable sources has produced a proliferation of wind turbines. Environmental impacts include safety, visual acceptability, electromagnetic interference, noise nuisance and visual interference or flicker. Wind turbines are large structures and can cast long shadows. Rotating blades interrupt the sunlight producing unavoidable flicker bright enough to pass through closed eyelids, and moving shadows cast by the blades on windows can affect illumination inside buildings.

Planning permission for wind farms often consider flicker, but guidelines relate to annoyance and are based on physical or engineering considerations rather than the danger to people who may be photosensitive.

Photosensitive Epilepsy

Photosensitive epilepsy (PSE) occurs in one in 4,000 of the population (Harding & Jeavons, 1994). The incidence is 1:1 per 100,000 per annum. Among 7–19 year-olds the incidence is more than five times greater (Fish et al., 1993). Photosensitivity persists in 75% of patients (Harding et al., 1997).

Precipitants

Sunlight is a precipitant of photosensitive seizures, whether reflected from waves, or interrupted as the subject travels past an avenue of trees or railings. In 454 patients Harding & Jeavons (1994) found 33 cases where seizures had been precipitated by flickering sunlight.

Television is a common precipitant of seizures and guidelines now prevent the broadcast of programs with flicker at rates exceeding 3 flashes per second, the frequency above which the chance of seizures is unacceptably high.

Flicker from Rotating Blades

The interruption of light by helicopter blades has caused seizures (Johnson, 1963; Gastaut & Tassinari, 1966; Cushman & Floccare, 2007) but to our knowledge there are no reports of seizures induced by rotating ceiling fans.

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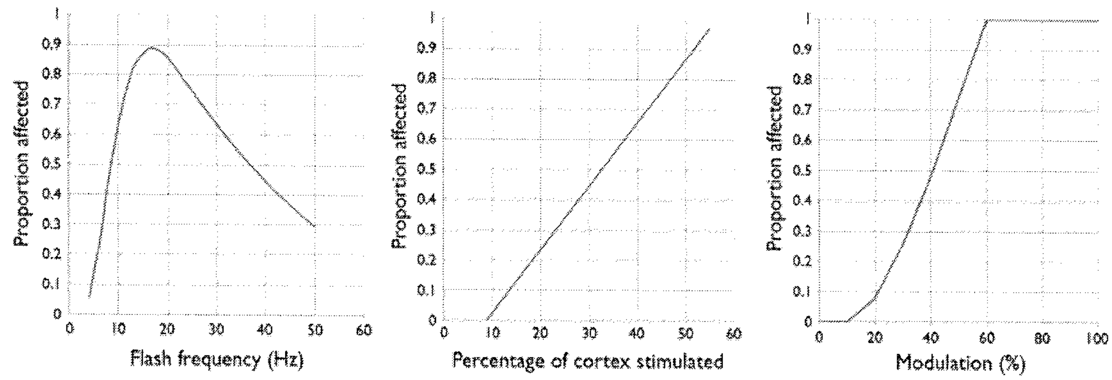

Figure 1.
Proportion of patients with photosensitive epilepsy sensitive to flicker, shown as a function of the frequency, the proportion of the cortex to which the flicker projects (estimated from the response to striped patterns, and the modulation depth of the flicker (expressed as a Michelson fraction). The data are taken from Binnie et al. (2002).
Epilepsia © ILAE

Large wind turbines usually rotate at between 30 and 60 revolutions per minute (rpm). Many are three-bladed and operate at a constant speed, and at 60 rpm produce flicker at a rate of 3 Hz; some two bladed wind turbines also exist. Turbines that rotate faster or have more blades will produce flicker at frequencies for which the chances of seizures are unacceptably high. Smaller variable-speed turbines range between 30 and 300 rpm (Verkuijlen & Westra, 1984) and some have more than three blades, so their flicker is within the range for which seizures are likely.

When several turbines are in line with the sun's shadow there is flicker from a combination of blades from different turbines, which can have a higher frequency than from a single turbine.

If the blades of a turbine are reflective then there is the possibility of flicker from reflected light at viewing positions that are unaffected by shadows.

Exposure to flicker from a turbine is determined by the hub height and the diameter of the blades, the height of the sun and the direction of the blades relative to the observer. These variables are affected by the time of day, time of year, wind direction, and geographical location (Verkuijlen & Westra, 1984). Shadows can be cast on the windows of nearby buildings, affecting the internal illumination giving rise to flicker that cannot be avoided by occupants. Verkuijlen & Westra determined the shadow tracks of wind turbines and their effect relative to the hub height of the rotor. They assumed that the rotor diameter was 75% of the hub height, but many wind turbines deviate from this ratio.

To avoid the problems of shadow flicker Verkuijlen and Westra proposed that wind turbines should only be installed if flicker frequency remains below 2.5 Hz under all conditions, and that wind turbines should be sited where buildings were not in East-NE or WNW directions from the turbine (northern hemisphere recommendations).

Two examples of seizures induced by wind turbines on small wind turbine farms in the UK have been reported to the authors in 2007.

The seizure-provoking effects of flicker depend on the time-averaged luminance of the flicker, its contrast, frequency and mark-space fraction and the area of retina stimulated, and are well described (Fig. 1).

The area of retina stimulated by flicker from a wind turbine might be expected to depend on the area that the rotors subtend at the eye. However, if the rotors interrupt direct sunlight casting a shadow upon the observer then the luminance of the flicker is likely to be such as to scatter sufficient light within the eye as to stimulate the entire retina with intermittent light. If the eyes are closed, the light is diffused by the eyelids, and intermittent light reaches the entire retina.

The luminance contrast ratio of the flicker depends on the extent to which the blades occlude the sun. Given that the sun subtends about 0.5 degrees, it is only completely occluded when the blades subtend more than 0.5 degrees at the eye, ignoring flare. When the observer is at a distance at which the blades subtend less than 0.5 degrees, the contrast of the flicker is reduced. Flicker ceases to be provocative at luminance contrasts less than about 10%, see Fig. 1. Assuming that contrasts of less than 10% occur when the width of the turbine blade subtends at the eye an angle that is 10% of the sun's diameter (0.05 degrees), it is possible to set a limit for the distance at which shadow flicker is likely to be seizure provoking. For a turbine blade 1 m in width, this distance is 1.14 km. Most shadows are likely to be of contrast sufficient to be provocative. It may be insufficient to restrict the siting of turbines to a distance 10 diameters from habitation (Clarke).

In EEG laboratories, epileptiform EEG activity is induced in photosensitive individuals by a xenon gas discharge lamp providing a series of very brief flashes, i.e., laboratory studies have not investigated the effect of very brief dark periods in an otherwise bright stimulus (such as might be provided by a wind turbine rotor). However, in the case of a seizure induced by helicopter blades reported by Cushman and Floccare (2007) the dark period of the shadow flicker was between 24 and 27 times per second. Helicopter blades are usually narrower than those on wind turbines and would provide for a shorter dark interval that might be expected to be less provocative than for a wind turbine blade.

Flashing can occur by the reflection of sunlight from the gloss surface of blades (Clarke). The blades are likely to cause flicker only if the amount of sun reflected toward an observer varies with the rotation of the blades. Given the shape of the blades, such variation is likely. These considerations introduce the possibility of a danger zone different from that provided by the shadow cast by the blades.

In the case of reflected sunlight, the flicker may be less bright than that cast by a shadow, and the light scattered within the eye may be insufficient to cause a problem. If so, the effectiveness of the stimulus will depend on the visual angle subtended by the rotor at the observer's eye. This visual angle will be directly proportional to the rotor length (radius) and the distance from which the observer is viewing the rotor.

The visual angle subtended by the flickering light determines the likelihood of seizures. From the studies of Binnie et al. (2002) or Wilkins et al. (2005) it is clear that the risk of seizures is in direct proportion to the area of visual cortex stimulated, see Fig. 1. For this reason, flicker that is directed at the center of the visual field is more provocative than flicker in the visual periphery. (The central 10 degrees of vision provide for 90%of the neural output from the retina to the brain.)

Suppose a turbine with blades 75% of hub height is viewed from a distance (Fig. 2). The sunlight is not simultaneously reflected from more than one blade given that the angle of the blades relative to the sun will rarely be similar. We will assume that the blades are of uniform width equal to 10% of their (radial) length. The angle at the eye of an observer subtended by any blade is maximum when the blade is at the bottom of its path. Assuming gaze is centered half way up the blade, the proportionate area of the visual cortex stimulated can be calculated (Drasdo, 1977). The proportion of visual cortex (P) to which a circular centrally fixated stimulus, angular radius A, projects is $P = 1 - e^{-0.0574A}$.

Applying this formula to angular segments of the rotor surface centrally fixated, the area of cortex to which the rotor projects can be calculated and the proportion of patients liable to seizures can be estimated, using the relationship between proportion affected and stimulated area of the cortex (Fig. 1). The proportion of patients affected is shown as a function of viewing distance (expressed as a factor of the height of the hub) (Fig. 3). Note that the risk of seizures does not decrease appreciably until the viewing distance exceeds 100 times the height of the hub, a distance typically more than 4 km.

The above analyses indicate that flicker from wind turbines is potentially a problem at considerable observation distances. Over 1 km, 25% of the light should be attenuated by the atmosphere (Curcio et al., 1953). Such attenuation should reduce the risk by a similar proportion (Binnie et al., 2003).

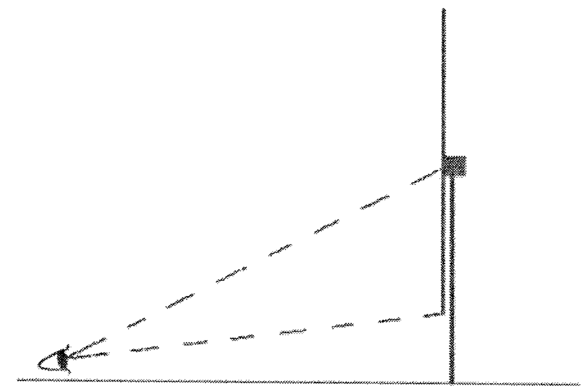

Figure 2.
Maximum visual angle is subtended by blades when at the bottom of their path.
Epilepsia © ILAE

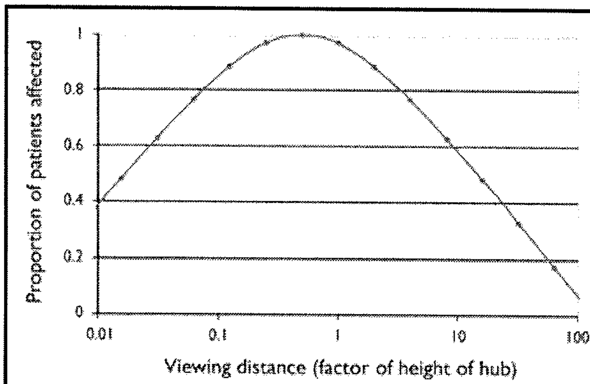

Figure 3.
Proportion of photosensitive patients liable to seizures from light reflected from a turbine blade shown as a function of viewing distance. The viewing distance is given as a factor of the height of the hub.
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Discussion

Flicker from turbines that interrupt or reflect sunlight at frequencies greater than 3 Hz poses a potential risk of inducing photosensitive seizures. At 3 Hz and below the cumulative risk of inducing a seizure should be 1.7 per 100,000 of the photosensitive population. The risk is maintained over considerable distances from the turbine. It is therefore important to keep rotation speeds to a minimum, and in the case of turbines with three blades ensure that the maximum speed of rotation does not exceed 60 rpm, which is normal practice for large wind farms. The layout of wind farms should ensure that shadows cast by one turbine upon another should not be readily visible to the general public. The shadows should not fall upon the windows of nearby buildings. The specular reflection from turbine blades should be minimized.

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Conflicts of interest: We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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A theory to explain some physiological effects of the infrasonic emissions at some wind farm sites

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For at least four decades, there have been reports in scientific literature of people experiencing motion sickness-like symptoms attributed to low-frequency sound and infrasound. In the last several years, there have been an increasing number of such reports with respect to wind turbines; this corresponds to wind turbines becoming more prevalent. A study in Shirley, WI, has led to interesting findings that include: (1) To induce major effects, it appears that the source must be at a very low frequency, about 0.8 Hz and below with maximum effects at about 0.2 Hz; (2) the largest, newest wind turbines are moving down in frequency into this range; (3) the symptoms of motion sickness and wind turbine acoustic emissions "sickness" are very similar; (4) and it appears that the same organs in the inner ear, the otoliths may be central to both conditions. Given that the same organs may produce the same symptoms, one explanation is that the wind turbine acoustic emissions may, in fact, induce motion sickness in those prone to this affliction.
 [http://dx.doi.org/10.1121/1.4913775]

[BSF] Pages: 1356–1365

I. INTRODUCTION

For at least four decades there have been reports in the scientific literature of people experiencing motion sickness-like symptoms attributed to low-frequency sound and infrasound. For example, Dawson (1982) makes the following points:

"Apart from the matter of acoustic fatigue in buildings and other structures, the main problem arising from excessive low frequency noise concerns people who can be disturbed, annoyed, made wretched or ill by acoustic insult to a degree which can be disruptive on a local scale and which nationally produces significant economic and social penalties."

He adds that: "[With] low frequency noise some people can be distressed to an extreme degree while others remain quite unaffected."

"Once a person has displayed some sensitivity to low frequency noise, further exposure lowers the sensitivity threshold."

"Any sensitivity is exacerbated by the presence of other stresses. The low frequency sensitivity syndrome includes: Feelings of irritation, unease, stress, undue fatigue, headache, nausea, vomiting, heart palpitations, disorientation, swooning, prostration."

Fifteen years later, Tesarz *et al.* (1997) reports much the same scenario: "In case studies of persons sensitive to low frequency noise, symptoms such as pressure on the eardrum or a pulsating feeling on the eardrum have been the most consistent result. Other symptoms that have been reported in both field and experimental studies are tiredness, irritation and uneasiness, difficulties to concentrate, headache, nausea and dizziness…."

Adopting the conclusions of Tesarz, Annex C, Clause C.1 of ISO 1996-1 (2003) states "…that the perception and the effects of sounds differ considerably at low frequencies as compared to mid or high frequencies." The text goes on to list six reasons for these differences. Two of these reasons are: (1) "perception of sounds as pulsations and fluctuations," and (2) "complaints about feelings of ear pressure." These are the same two effects as those listed in the preceding text by Tesarz as "most consistent."

Now these same problems are appearing in the vicinity of wind farms, and as in 1982 and earlier, nobody understands how these problems arise; nor is it understood why only a fraction of the population is affected.

The purpose of this paper is to provide a foundation upon which the reported effects of infrasound from wind turbines may be investigated. This paper presents a theory upon which needed investigations can go forward. The Appendix outlines some elements of a research statement.

II. DATA FROM A PROBLEM SITE

A. Observations from people affected by the installation of wind turbines

One wind farm that is experiencing these problems is in Shirley, WI. Here three families have abandoned their homes

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because family members who became ill after installation of the turbines could not acclimate to the situation.[1] Because of these conditions in Shirley, a study was conducted with the proposed test plan calling for the wind farm owner to cooperate fully in supplying operational data and by turning off the units for short intervals so the true ON/OFF impact of turbine emissions could be documented. The owner declined this request citing the cost burden of lost generation from the eight turbines at the Shirley site.

Four acoustical consulting firms cooperated to jointly conduct this study: (1) Channel Islands Acoustics (ChIA), (2) Hessler Associates, Inc., (3) Rand Acoustics, and (4) Schomer and Associates, Inc.

This study was conducted during a 3-day period in December, 2012. The first task accomplished was to meet with residents having problems with the wind turbine acoustic emissions including members of the three families who had abandoned their homes. These discussions with the residents yielded the following observations:

(1) At most locations where these various symptoms occurred, the wind turbines were generally not audible. That is, these problematic symptoms are devoid of noise problems and concomitant noise annoyance issues. The wind turbines could only be heard distinctly at one of the three residences examined, and they could not even be heard indoors at this one residence during high wind conditions.
(2) Some residents reported that they could sense when the turbines turned on and off; this was independent of hearing or seeing the turbines. This assertion by the residents is readily testable, and a plan to test this assertion is briefly summarized in the Appendix.
(3) The residents reported "bad spots" in their homes but pointed out that these locations were as likely to be "bad" because of the time they spent at those locations as because of the "acoustic" (inaudible) environment. The residents did not report large changes from one part of their residences to another.
(4) The residents reported little or no change to the effects based on any directional factors. Effects were unchanged by the orientation of the rotor with respect to the house; the house could be upwind, downwind, or crosswind of the source.
(5) Many of the residents reported motion sickness like symptoms as adverse effects associated with the wind turbines.

Two of the major implications of these five findings are: (1) Because these residents largely report wind turbines as inaudible, it seems that suggestions some have made that these conditions are being caused by extreme annoyance can be ruled out and (2) the lack of change with orientation of the turbine with respect to the house and the lack of change with position in the house suggest that we are dealing with very low frequencies; frequencies such that the wavelength is a large fraction of the wind-turbine diameter (i.e., about 3 Hz or lower).

It should be mentioned that there are about 120 residences within about 5000 ft of the closest turbine; this suggests that there are about 275 residents. Of these 275 residents, 50 have described adverse effects that they have experienced after the introduction of the wind turbines. It is not known how many of the 120 residences are "participating," but most agreements for participating residences include some form of confidentiality and non-complaint clauses.[2]

The most common complaints are feelings of pressure and pulsations in the ears. And this is very much in accordance with ISO 1996-1 (2003) where, as discussed in the preceding text, these two factors are listed as the most common effects of low-frequency noise. However, in this paper, we are concentrating on sea-sickness like symptoms.

B. Physical measurements

Figure 1 is an aerial photo of the Shirley wind farm. This figure shows the positions of five of the eight wind turbines that make up this site, Nordex N-100 s, and the position of the three abandoned residences. Primary measurements were made at residences 1–3 on consecutive days.

Bruce Walker of Channel Island Acoustics employed a custom designed multi-channel data acquisition system to measure sound pressure in the time domain at a sampling rate of 4000/s where all signals are collected under the same clock. The system is calibrated to be accurate from 0.1 Hz thru 10 000 Hz. Measurements were made both inside and outside the house to gather sufficient data for applying advanced signal processing techniques.

George and David Hessler of Hessler Associates, Inc., employed four off-the-shelf type 1 precision sound level meter/frequency analyzers with a rated accuracy of ± 1 dB from 5 to 10 000 Hz. Two of the meters were used as continuous monitors to record statistical metrics for every 10-min interval over the 3-day period.

Robert Rand of Rand Acoustics observed measurements and documented neighbor reports and physiological effects including nausea, dizziness, and headache. He used a highly accurate microbarograph to detect infrasonic pressure modulations from wind turbine to residences.

Paul Schomer of Schomer and Associates, Inc., observed all measurements. Among other things the following observations are made based on the results of the physical measurements. In particular, these observations are based upon the coherence calculations by Bruce Walker. Figure 2 shows the coherence between the outdoor ground plane microphone and four indoor spaces at residence 2: The living room, the master bedroom, behind the kitchen, and in the basement. The data collected at residence 2 were measured with only 58% of turbine power, although the wind conditions were optimal for turbine operation, and the power was much less than 58% during the measurement periods at R1 and R3.

It is inferred from the residents' observations that the important effects result from very low frequency infrasound of about 3 Hz or lower. We can test this assertion with the data collected at the three residences at Shirley. Only residence 2 was tested during a time when significant power was being generated, so it is the only source of data used herein. Figure 2 shows the coherence between the outdoor ground plane microphone and the four indoor spaces listed above

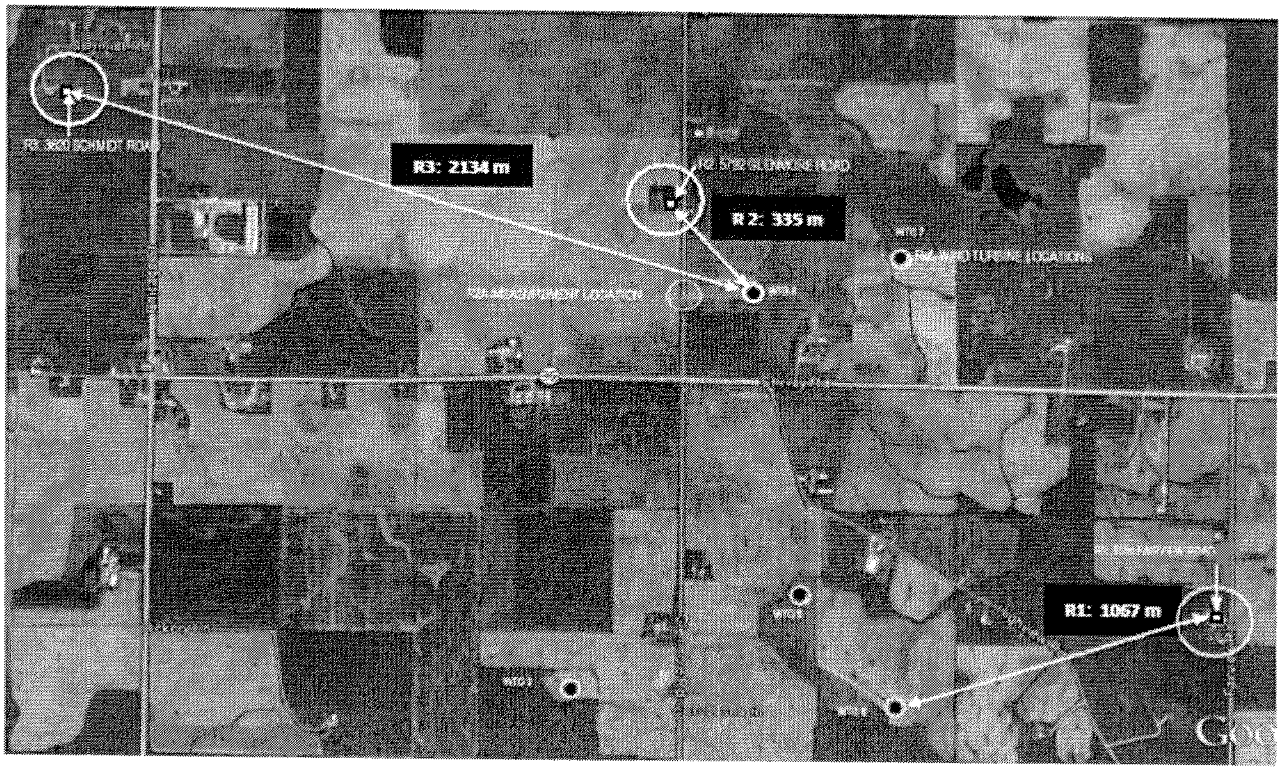

FIG. 1. Aerial photograph of the site showing the three residences and the five closest wind turbines.

for the frequency range from 0.5 to 7 Hz. All of the four spaces exhibit coherence at 0.7, 1.4, 2.1, 2.8, and 3.5 Hz, and in this range, there is no coherence indicated except for these five frequencies. The basement continues, with coherence exhibited at these higher harmonically related frequencies of 4.2, 4.9, 5.6, 6.3, and 7 Hz. The three indoor microphones situated on the first floor exhibit only random zones of high and low coherence as a function of frequency but not so as to correspond to other microphones in the house. That is, above 5 Hz the three indoor microphones exhibit only random periods of coherence, and above 7 Hz the basement microphone exhibits only random periods of coherence. But all four microphones are lock step together in their coherence with the outdoor microphone below about 4 Hz.

As an analysis that is complementary to the coherence plots of Fig. 2, Fig. 3 shows spectral plots of data collected at residence 2. As in the coherence plots, one can see the first several harmonics of the wind-turbine blade-passage frequency, 0.7 Hz, and nothing notable above about 7 Hz. Two channels of measurement are shown on Fig. 3, the outside, ground plane microphone (upper curve), and the indoor microphone in the living room (lower curve). Note that the pressures that result from the acoustic emissions of the wind turbines, when measured indoors, keep growing as the frequency goes lower because the entire house is behaving like a closed cavity.

Based on this analysis of the spectral and coherence data, we conclude that the only wind turbine-related data

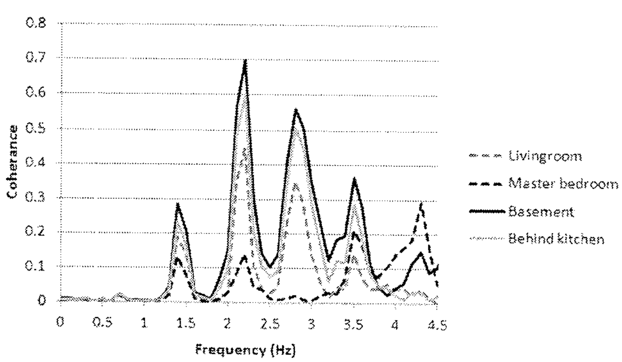

FIG. 2. Coherence between the each of the four indicated rooms with the outdoor-ground plane microphone.

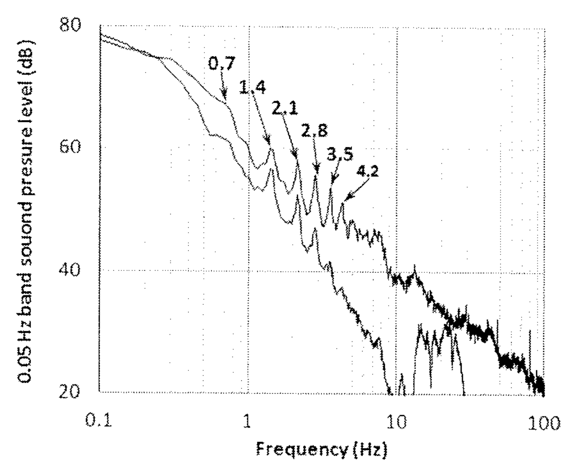

FIG. 3. Spectral plot of the ground-plain outdoor microphone data (upper trace) and indoor data measured in the living room of Residence 2 (lower trace).

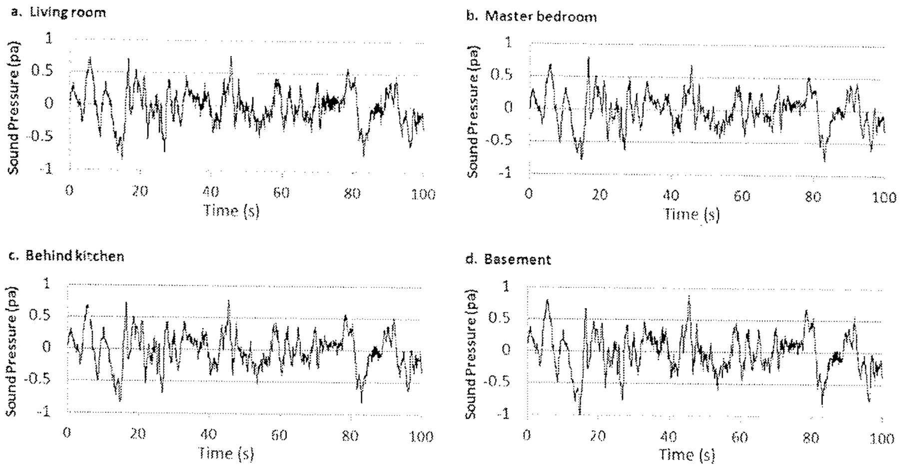

FIG. 4. Sound pressure versus time for of the data collected at the four indoor measurement locations indicated in Fig. 2 and for the first minute of data from the data set used for Fig. 2. Note that the sound pressure versus time is very similar for all indoor locations.

evident in the measurements at residence 2 are the very low frequencies ranging from the blade passage frequency of 0.7 Hz to up to about 7 Hz. This conclusion is consistent with the residents' reports that the effects were similar from one space to another but a little to somewhat improved in the basement, the effects were independent of the direction of the rotor and generally not related to audible sound.

Figure 4 shows the sound pressure level for the first minute of the 10 min represented on Fig. 2, above. This figure, which is sensitive to the lowest frequencies, shows that at these very low frequencies, the sound pressure levels in all four spaces are quite similar. The small changes from different positions in the house also suggests that the house is small compared to the wavelength so that the insides of the house are acting like a closed cavity with uniform pressure throughout being driven by very low-frequency infrasound.

The measurements support the hypothesis developed in the preceding text that the primary frequencies are very low, in the range of several tenths of a hertz up to several hertz. The coherence analysis shows that only the very low frequencies appear throughout the house and are clearly related to the blade passage frequency of the turbine. As Fig. 4 shows, the house is acting like a cavity and indeed at 5 Hz and below, where the wavelength is 60 m or greater, the house is small compared to the wavelength.

While we would have liked to have been able to draw conclusions on measurements at all three sites, that was not possible because the energy company was not generating much power during the measurements of R1 and R3, and even just over 50% during the measurements at R2.[3]

III. THE MOTION SICKNESS HYPOTHESIS

A. The Navy's nauseogenic region

As a starting point we consider a paper by Kennedy *et al.* (1987) entitled: "Motion sickness symptoms and postural changes following flights in motion-based flight trainers." This paper was motivated by Navy pilots becoming ill from using flight simulators. The problems encountered by the Navy pilots appear to be similar to those reported by about five of the Shirley residents. This 1987 paper focused on whether the accelerations in a simulator might cause symptoms similar to those caused by motion sickness or seasickness. Figure 5 (Fig. 1 from the reference) shows the advent of motion sickness in relation to frequency, acceleration level and duration of exposure. To develop these data, subjects were exposed to various frequencies, acceleration levels, and exposure durations, and the Motion Sickness Incidence (MSI) was developed as the percentage of subjects who vomited. Figure 5 shows two delineated regions. The lower region is for an MSI of 10%. The top end of this region is for an exposure duration of 30 min and the bottom end is for 8 hr of exposure. The upper delineated region has the same duration limits but is for an MSI of 50%.

What is important here is the range encompassed by the delineated regions of Fig. 5. Essentially, this nauseogenic condition appears to occur primarily below 1 Hz. Note that the Navy criteria are for acceleration, while in Shirley we are dealing with pressures in a closed cavity, the house. The similarity between force on the vestibular components of the inner ear from acceleration and pressure on these from being in a closed cavity suggests that the mechanisms and frequencies governing the nauseogenic region might be similar for both pressure and acceleration, and much of this paper is concerned with showing the plausibility of the ear responding in like fashion to accelerations of a moving vehicle and acoustic pressures at these same infrasonic frequencies (e.g., 0.7 Hz).

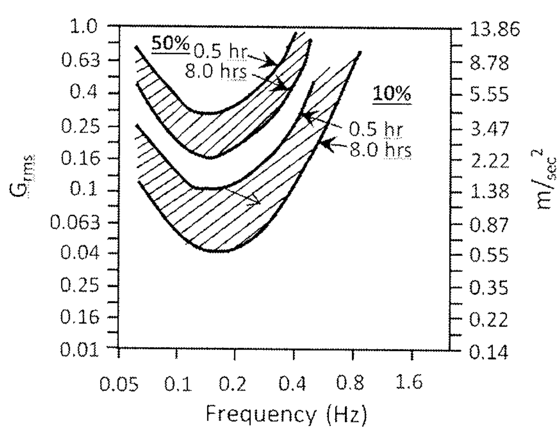

FIG. 5. The nauseogenic region as developed by the U.S. Navy (after Kennedy *et al.*, 1987).

As the generated electric power of a wind turbine doubles, the sound power doubles and the blade passage frequency decreases by about 1/3 of an octave (Møller and Pedersen, 2011).[4] The wind turbines at Shirley have a blade passage frequency of about 0.7 Hz. This suggests that a wind turbine producing 1 MW would have a blade passage frequency of about 0.9 Hz, and on Fig. 5, a change from 0.7 to 0.9 Hz requires a doubling of the acceleration for the same level of response. Thus it is very possible that this nauseogenic condition has not appeared frequently heretofore because older wind farms were built with smaller wind turbines. However, the 2.5 MW, 0.7 Hz wind turbines clearly have moved well into the nauseogenic frequency range.

B. Motion sickness like symptoms and their implications

We systematically listed the symptoms of low frequency noise, as given by the two papers cited in the preceding text (Dawson, 1982; Tesarz *et al.*, 1997), and on the same basis, we listed the symptoms of sea-sickness, using two journal papers (Stevens and Parsons, 2002; Bittner and Guignard, 1988) and the symptoms listed by the National Health Service (2014) and C-Health (2013). Table I compares the various frequencies of the indicated symptoms of seasickness and low-frequency infrasound sickness from this published literature. The two sets of symptoms are strikingly similar.

Motion sickness, or kinetosis, is generally related to the vestibular, visual, and somatosensory systems (cf. Griffin, 1990). A common theory of the cause of kinetosis is that of sensory conflict: The information received from two or more sensory systems conflict (e.g., visual inputs in a closed room and vestibular inputs from a rolling boat) producing symptoms similar to that of ingesting a poisonous substance. The result is an evolutionary protective response to rid the body of a harmful foreign substance. Thus motion sickness is not really a sickness but rather is a natural reaction to unusual input information.

At the start of this analysis, the working hypothesis was that wind turbine noise somehow, because of the nauseogenic regions similarity, created symptoms that were similar to those of motion sickness. We now have a much simpler hypothesis—just as some people experience motion sickness when watching movies and videos, wind-turbine acoustic emissions trigger motion sickness in those who are susceptible; it is another form of *pseudo-kinetosis*.

TABLE I. Percent of references citing symptom indicated.[5]

	Composite of four sea sickness studies or information papers	Composite of two low frequency "sound" sickness studies
Not feeling well	100	100
Dizziness	100	100
Headache	100	100
Nausea and vomiting	100	100
Sleepiness, drowsiness, and sleep disturbance	75	100
Fatigue and tiredness	75	100
Difficulty thinking	25	50
Irritation	25	100
Sweating	100	0
Pale	75	0

At Shirley, of the 50 people who reported symptoms after the introduction of wind turbines to the area, 5 of those 50 people reported symptoms similar to motion sickness. We simply have no information on other area residents, except for these 50, and do not know how many of the other residents are participating.[3] Based on the sample of 5 of 50, we can say that the incidence of motion sickness symptoms at Shirley is 10% or less, a figure that is clearly in line with the expected percentage of those in the general population affected by motion sickness.[6] In fact, Montavit (2014) indicates that "about 5% to 10% of the population is extremely sensitive to motion sickness; 5% to 15% are relatively insensitive; and about 75% are only subject to it to a 'normal,' i.e., limited degree."

In our meeting with affected residents discussed in the preceding text, it was stated that each person affected by the wind farm noise in the form of motion sickness symptoms was also motion sickness sensitive. The same is true for Rob Rand and Steve Ambrose, who are two acoustical researchers who have themselves reported suffering strong symptoms from low frequency wind-turbine emissions.

As noted in the preceding text, inconsistent proprioception, accelerations, and visual cues may not be resolved and cause a defensive emetic response. For example, during a car trip, nerves and muscle receptors do not register any movement because the body itself is sitting still. The eyes, on the other hand, send the brain a message of fast motion. The equilibrium organ in the inner ear delivers information of curves, acceleration, and/or ascents that contradict the messages from the other two sources. This contradictory flood of impulses and information overburdens a healthy sense of equilibrium that the brain, in turn, interprets as a danger situation. It then releases stress hormones, which in turn create symptoms of dizziness and nausea.

So to induce a sense of motion where none exists and thereby create the sensory conflict that is requisite to induce motion sickness requires that the acoustic signal cause the vestibular system to "tell the brain" it is accelerating when the ocular system is telling the brain there is no motion.

IV. EXCITATION OF THE OTOLITH

A. The middle ear and inner ear

As shown on Fig. 5, the Navy criteria for the likelihood of sea sickness are functions of three factors: (1) Duration of exposure to the motion, (2). amplitude of the acceleration, and (3) frequency of the acceleration. Moreover, because the blade passage frequency has been decreasing and the acoustic power has been increasing as the turbines get larger, one can imagine a future with greater, more frequent problems like those in Shirley (Møller and Pedersen, 2011) (footnote 4). There is one main question that greatly affects the likelihood of this eventuality. This main question relates to the fact that the Navy criteria are based on acceleration, while the wind-turbine acoustic emissions are very low frequency acoustic pressure waves.

In the following, we show only that it appears that an acoustic wave at 0.5–0.7 Hz can generate a similar response as the signal generated by acceleration at 0.5–0.7 Hz. This discussion analyzes the linear motion sensing function of the ear and explains how the ear could respond to wind turbine emissions. We are concerned primarily with the inner ear.

Figure 6 shows just the inner ear, which contains the cochlea, the organ that transforms the sound wave into locally acting vibration at frequencies ranging from about 10 Hz to about 20 kHz (Obrist, 2011). The inner ear also contains the vestibular system, which controls and facilitates balance and motion. The system of semicircular canals has evolved to be able to sense rotational movements of the head while remaining rather insensitive to forces arising either from translational acceleration of the body or gravity: The cupulae normally have a similar specific gravity to that of the endolymph. The vestibular perception of translational forces originates normally from sensory systems (maculae) located within the utricle and saccule.

As shown in Fig. 7, the classical description for the maculae are flat gelatinous masses (otollithic membrane) covered with minute crystals (otoconia) connected to an area of the utricle and saccule by cells, including hair cells. A suitably oriented translational force will cause the mass to exert a shear force, resulting in a variation in the firing rate of the hair cells. The maculae cover an area of a few square millimeters. They are located on the floor and lateral wall of the utricle and, in an orthogonal plane, on the anterior wall of the saccule (Griffin, 1990).

These six inner ear organs, the cochlea, the three SCCs, the saccule, and the utricle, open into the inner space, the vestibule. The inner ear is divided into distinct fluid-filled chambers containing perilymph and endolymph. A hard bone and fluid (perilymph) surrounds the scala media, which are filled with endolymph, and the only openings to the "outside" are two windows, the round window, which separates the air-filled middle ear from the fluid-filled inner ear by a thin membrane, and the oval window, which connects to the stapes, and also separates the inner ear from the middle ear by means of a thin (round window) membrane (Obrist, 2011).

As the acoustic pressure impinges on the tympanic membrane, it travels through the middle ear and into and through the inner ear from the oval window to the round window. Like a transformer in an electric circuit, the middle ear increases the pressure by 29 dB with a corresponding decrease in velocity. This transformer matches the impedance of air to the impedance of the inner ear fluids. At high frequencies, the tympanic membrane develops modes that affect the transmission of sound across the middle ear. Low frequencies do not create these vibration modes and the membrane vibrates as a "plate." The round window is compliant and responds to the pressure wave that travels up the scala vestibuli and down the scala tympani to create shear forces in the cochlea. These two "tunnels" surround the basilar membrane. Additionally, there is a communication between the scala vestibuli and the vestibular system by means of which acoustic pressure might be transmitted to the otoliths.

B. Classical model of the otolith

We have shown there is a plausible path for the infrasound pressures to reach the inner ear and in particular the otoliths. The classical model of the otolith is shown pictorially in Fig. 7. The otoconial layer is a rather dense, firmer layer of the otolith. It thickens at the surface. The otoconial layer gets its density from embedded calcium carbonate crystals (otoconia). The otoconial layer creates an inertial force when accelerated owing to its mass. This force is transferred to the gel layer (cupula), which then bends the hair cells causing them to transmit signals to the brain. Figure 7 shows in a simple way how the mass in the otoconial layer creates an inertial force that results in shear forces in the cupula and bending of the hair cells coupled into the cupula. So the fundamental measurement by the otolith is the inertial force of the otoconial layer (Grant and Best, 1986); the otolith is measuring force.

C. Calculations of forces acting on the otolith

In this section, we approximate and compare two potential forces acting on the otoliths: (1) Inertial force to accelerations and (2) forces due to the instantaneous pressure in an acoustic wave.

Although the more complete solution for modeling the motion of the otolith is given by a parabolic partial differential equation (Grant and Best, 1986), the frequency response of the otoliths is flat from DC to about 10 Hz (McGrath, 2003), the

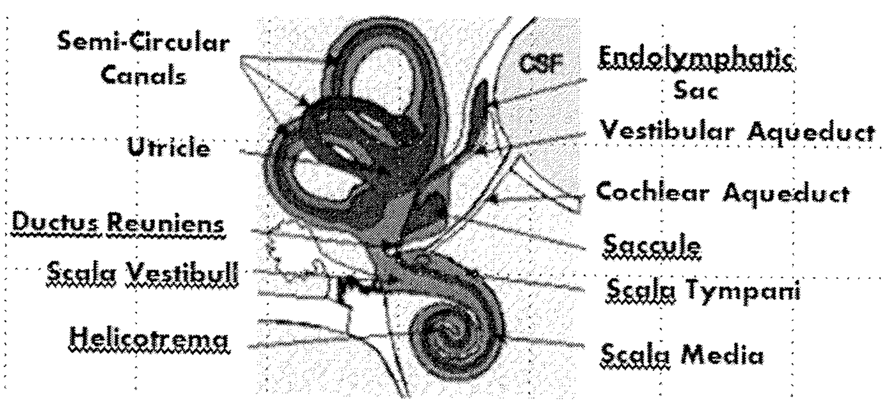

FIG. 6. The inner ear (after Salt, unpublished data).

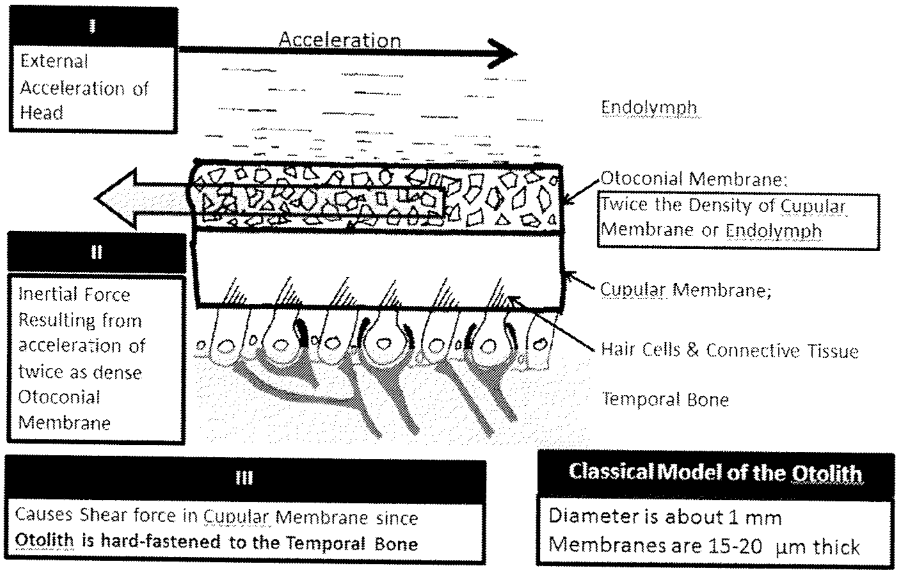

FIG. 7. Schematic sectional drawing of the classical model for the otolith.

position of the poles in the response being functions of assumptions for values of certain parameters describing physical attributes of the layers and their constituents. For an order of magnitude calculation, we simply consider $F = \mathrm{ma}$, where the acceleration is precisely the acceleration of the head, and the mass is the differential density of the otoconial layer minus the density of the surrounding fluid and the cupular membrane times the volume of the otoconial layer. Although calcium carbonate has a density of $2.7\,\mathrm{g/cm^3}$, the density of the otoconial layer is taken to be $2\,\mathrm{g/cm^3}$ because it is a combination of the dense calcium carbonate and the less dense gel material. The density of the cupular membrane and of the endolymph, which has properties given as being similar to water, is taken as $1\,\mathrm{g/cm^3}$, so the differential density is $1\,\mathrm{g/cm^3}$ or $1000\,\mathrm{kg/m^3}$. As can be seen in the classical model of the otoliths (Fig. 7), they are approximated as round and their diameter is about 1 mm. The thickness of the otoconial layer has been given as $15–20\,\mu$m (Grant and Best, 1986). Therefore we calculate: the mass = density ∗ height ∗ top surface area or, mass(kg) $= 10^3\ (\mathrm{kg/m^3}) * 18 * 10^{-6}\ \mathrm{m} * \pi * 0.5 * 10^{-3} * \mathrm{m} * 0.5 * 10^{-3} * \mathrm{m} = 18 * \pi/4 * 10^{-9} \approx 1.4 * 10^{-8}\,\mathrm{kg}$, where density $= 10^3$ (kg/m^3), height $= 18 * 10^{-6}$ m, and top surface area $= \pi * 0.5 * 10^{-3} * \mathrm{m} * 0.5 * 10^{-3} * \mathrm{m}$. With reference to Fig. 7, we take the acceleration to be $5\,\mathrm{m/s^2}$, so the acceleration force,

$$F_{\mathrm{accel}} = 7 * 10^{-8}\mathrm{N}.$$

In terms of the pressure of an acoustic wave, we take the sound pressure level (SPL) to be 54 dB, which corresponds to 0.01 Pa, and because of the "transformer" function of the middle ear, we assume a 29 dB gain in pressure. Therefore the acoustic force, $F_{\mathrm{acous}} = 28 * 0.01 * \pi/4 * 10^{-6}\,\mathrm{N} \approx 22 * 10^{-8}\,\mathrm{N}$.

D. Excitation of the otoliths

More recent research tends to confirm the model presented in the preceding text for the excitation of the saccule. It is shaped something like an elongated hemi-sphere with the base of the hemi-sphere rigidly attached to the temporal bone and the otoconial layer on the top where under the force of acceleration shear forces can be set up in the cupula. However, there is radically new information about the utricle. Uzun-Coruhlu *et al.* (2007) have used x-ray microtomography and a method of contrast enhancement to produce data revealing "that the saccular maculae are closely attached to the curved bony surface of the temporal bone as traditionally believed, but the utricular macula is attached to the temporal bone only at the anterior region of the macula" (see Fig. 8). This changes the model for excitation of the utricular macula. According to Uzun-Coruhlu *et al.* in the classical view of the utricular macula

"…the sub-surface of utricular macula is implied (if not actually stated) to be rigid; these models do not accommodate the "floating" utricular macula which we have shown and which is consistent with other anatomical evidence (e.g. Schuknecht, 1974). Since the hair cell receptors on the utricular macula are stimulated by forces there would be a major difference in modeling the sensory transduction of the macula to such forces if the forces acted on a tenuously supported flexible membrane or acted on a membrane which is rigidly attached to bone. As an example, modeling the magnitude of utricular hair cell displacement to an increased dorso-ventral g-load during centrifugation will be quite different if the whole membrane is deflected by the g-load or if it remains fixed in place. The latter rigid attachment has been explicitly or tacitly assumed, whereas our results show the macula is not rigidly attached to bone."

"The key information which is now required for realistic modeling of utricular transduction is information about the flexibility of the utricular membrane to determine the extent to which it would be deflected by such forces."

Essentially, Uzun-Coruhlu *et al.* are saying that the excitation of the otolith in the utricle depends on the flexibility of the utricular macula. Because the macula is not rigidly attached to the temporal bone, the classical model (Fig. 7) for excitation of the otolith by acceleration does not work. One way for inertial forces on the otolith to create bending forces is if the stiffness of the utricular membrane varies with position. Then inertial forces on the otolith will make

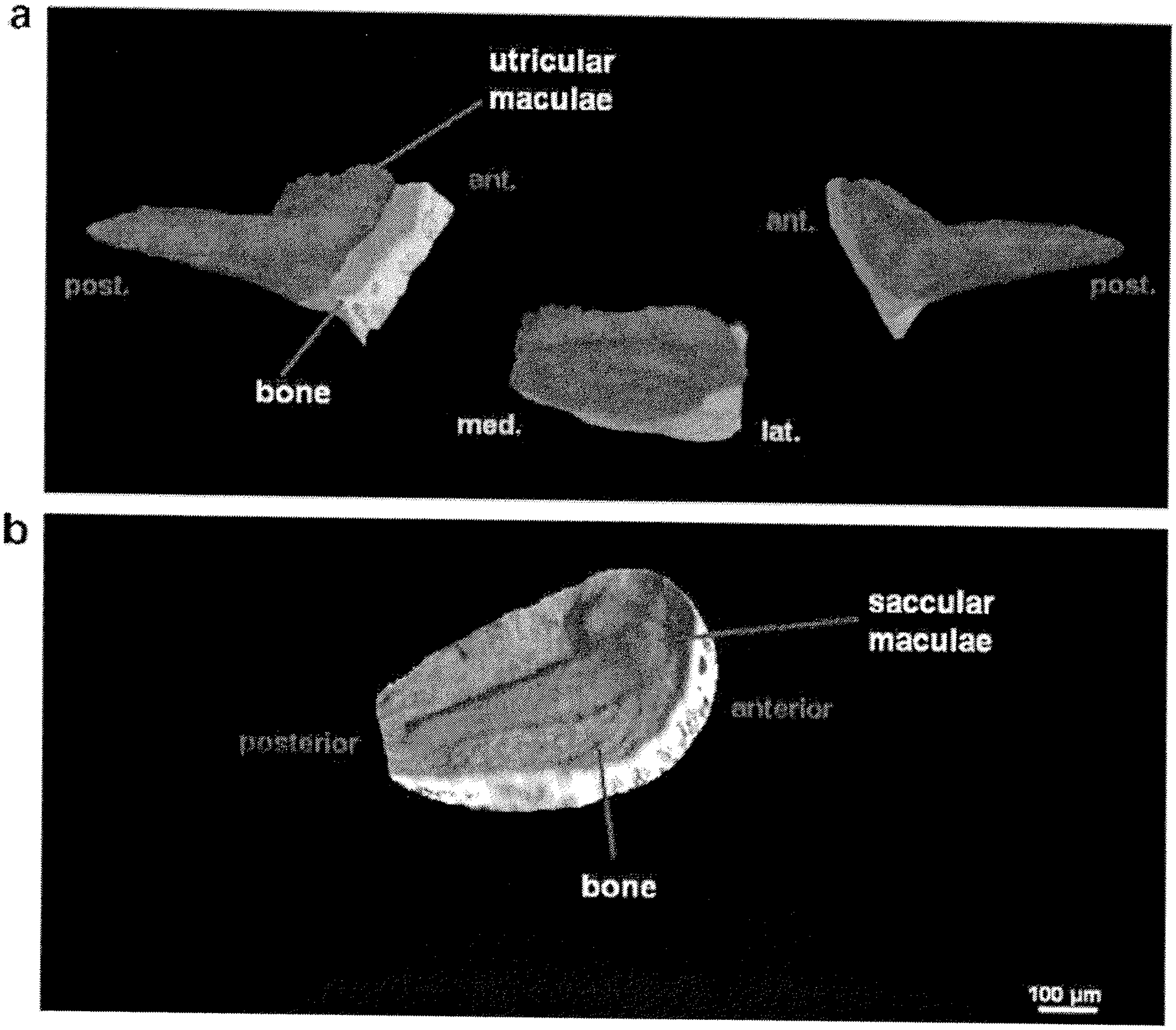

FIG. 8. (Color online) Artist rendered three-dimensional images of the utricular and the saccular maculae of a guinea pig (from Uzun-Coruhlu *et al.*, 2007).

the otolith "bulge" where it is less stiff and contract where it is stiffer, producing bending forces that will trigger the hair cells. Precisely the same thing will happen if the force is externally applied through the endolymph as when the force is internally applied through the otoconial layer. In this model, if there is external force on the utricle, it will expand where it is less stiff and contract where it is stiffer. In particular, the acoustic pressure that reaches the otolith through the eardrum and middle ear pathway described earlier should cause the utricular macula to signal the brain in virtually identical fashion to signals generated by inertial forces, i.e., forces generated by acceleration of the head. That is, the utricular macula should respond in like fashion to acoustic pressure fluctuations and direct acceleration of the head at the same frequency.

E. An example that indicates these theories may be correct

The pressure in the endolymph is a scalar; its "direction" is everywhere normal to the surface. Therefore in contrast to true inertial forces that are vectors, the acoustic pressure will always excite the same hair cells independent of the orientation of the head. So one who experiences this effect should always feel the same motions. And this is exactly what both Steve Ambrose and Rob Rand, who are both acousticians, each experienced. Rob Rand, one of the acoustical researchers on this project, the one who is sensitive to wind turbine acoustic emissions, said of his work in Falmouth, MA in April 2011: "I went outside hoping to feel better. I looked straight at a tree with my eyes, and my brain said the tree was about 20 to 30 degrees elevated and about 20 to 30 degrees to the right. Then I tried to focus on a bush looking straight at it, and again my brain said the bush was off to the right and elevated at about the same angle as before; and the same for the house. For everything I looked at, immediately my brain would say it was elevated and off to the right." Steve Ambrose had exactly the same experience, only not the same angles.

V. CONCLUSIONS

The wind turbine clearly emits acoustic energy at the blade passage frequency, which for the Nordex N100 is

0.7 Hz and about the first six harmonics of 0.7 Hz. This very low infrasound was only found at R2, but that was the only day in which significant power was being generated (about 58%).

Most residents do not hear the wind-turbine sound; noise annoyance is not an issue. The issue is physiological responses that result from the very low frequency infrasound and that appears to trigger motion sickness mainly in some of those who are susceptible to it. These results suggest a relation between wind turbines and motion sickness symptoms in what appears to be a small fraction of those exposed. This finding does not prove our hypothesis that the otoliths are responding to the wind turbine infrasonic emissions. Rather, we can say that the pathway for inducing this condition appears to be the same as airborne transmission through the middle ear and thence to the vestibular sensory cells, but confirmatory research of the pathway is recommended.

Finally, it is shown that the force generated on the otoliths by the pressure from the infrasonic emissions of the wind turbines is perhaps three times larger than the force that would be generated by an acceleration that was in accordance with the U.S. Navy's nauseogenic criteria (Fig. 5 herein). That is, a 0.7 Hz "tone" at 54 dB produces about the same to three times the force as does a $5\,m/s^2$ acceleration.

VI. ADDITIONAL RESEARCH AND DATA COLLECTION RECOMMENDATIONS

Research to date has not tended to study the effects on humans reported anecdotally in what is probably a minority of wind farms even though these reports are exactly what is to be expected in accordance with ISO 1996-1 (2003). This paper provides part of the foundation upon which such research could be accomplished. Some of the necessary research is listed below. The first item in the list, perform sensing, is discussed in more detail in the Appendix.

(a) Perform the "sensing" tests outlined in the Appendix of this paper.
(b) Demonstrate electric signals going to the brain that emanate from the otoliths; signals that are in sync with the wind turbine emissions, where depending on method this testing would be done with surrogate species.
(c) Develop an understanding of why this phenomenon seems to affect residents near only a small minority of wind farms.
(d) Establish who is and who is not affected by wind turbine infrasonic emissions in various ways.
(e) Establish why this all occurs.

Currently the wind turbine industry presents only A-weighted octave-band[7] data down to 31 Hz, or, frequently 63 Hz, as a minimum. They have stated that the wind turbines do not produce low frequency sound energies. The measurements at Shirley have shown that low frequency infrasound is clearly present and relevant. As indicated by ISO 1996-1 (2003), A-weighting is inadequate and inappropriate for description of infrasound.

ACKNOWLEDGMENTS

The authors wish to acknowledge the extraordinary effort and trust that went into making the testing at the Shirley wind farm possible. First, there is the extraordinary effort of David and George Hessler and their client, Clean Wisconsin, who made these tests happen at the Shirley wind farm. Coupled with this effort were the extraordinary efforts by Glen Reynolds and Forest Voice who also made this test happen. Additionally, our acknowledgment goes to George Hessler for repeated reviews of the paper with helpful inputs and questions, and much credit is due to Bruce Walker for his development of a custom multi-channel time-domain very low frequency, 0.1 Hz, measurement system necessary for advanced signal processing and analysis between and among channels and his custom reprinting of the coherence and spectral plots herein from Shirley. Additionally, credit goes to Robert Rand for repeatedly being a firsthand source of knowledge about the effects of wind turbine emissions and for general thoughts and ideas. Our acknowledgment goes to Dr. Sarah Laurie (Southern Australia), Dr. Robert McMurtry (Ontario, Canada), and Dr. Jay Tibbitts (central Wisconsin); three physicians from around the world who searched their records to provide information on symptoms and histories. And finally, acknowledgments, Alec Salt for providing key references about the otoliths that led us in the right direction; Sumuk Sundarum, MD Ph.D. internal medicine, for review of an early draft; Stephen Chadwick, MD otolaryngology, for initial ideas and review of an early draft; Paul Schomer's good friend Michael Rosnick, MD family medicine, for correcting a misconception about the Eustachian Tube; and to Paul Schomer's daughter Beth Miller, Ph.D., for initial lessons and information on the anatomy and physiology of the ear.

APPENDIX: A TEST FOR PERCEPTION OF THE ACOUSTIC EMISSIONS FROM WIND TURBINES

In Shirley, residents stated that some of them could sense the turning on and off of the wind turbines without any visual or audible clue. This assertion is readily tested; however, it requires the cooperation of the energy company.

Consider the two houses at Shirley where there is no audible sound; the R-1 house and the R-3 house. The residents of the houses, and others who would be subjects, would arrive at the house with the wind turbines off. The test itself would take something like 2 h to perform. Sometime during the first hour, the wind turbines(s) that had been designated by the residents as the turbines they could sense, might or might not be turned on. It would be the residents' task to sense this "turn on" within some reasonable time designated by the residents–say 10 or 30 min. Correct responses (hits) would be sensing a "turn on" when the turbines were turned on, or sensing no change if they were not turned on. Incorrect responses (misses) would be failure to sense a turn on when the turbines were turned on, or (false alarms) would be "sensing" a turn on when the turbines were not turned on.

Similar tests could not necessarily be done starting with the turbines initially on because the subjects, when sensitized find it more difficult to sense a turn off.

[1]The family in the closest dwelling, R-2, reported that the wife and their then 2-yr-old son had the problems; the husband did not have problems. This totally stopped upon their leaving the vicinity of the wind turbines.

[2]Traditionally, participating households are those that receive a share of the proceeds in exchange for having wind turbines or ancillary facilities or equipment on their property. As a part of these agreements, these households are required to agree to not complain about the wind turbines. At Shirley, the energy company also had their "good" neighbor policy wherein all residents who were not eligible to be participating were offered payments for agreeing not to make complaints or take any legal action.

[3]A report, including conclusions and recommendation, was written and signed by these five Shirley technical participants. One of the many interested parties and /or legal entities did not like the conclusions and expunged these from the report without obtaining the approval of the authors while retaining the signature block as it was. Both versions were eventually placed in the record and the complete version as written and signed can be found at the following link: http://psc.wi.gov/apps40/dockets/conten/detail.aspx?dockt_id=2535-CE-100c, go to *"Documents"*; then to "January 2, 2013, 8:40 A.M." (Ex. -Forest Voice-Rand2) (Last viewed 9/29/2014).

[4]Møller and Pedersen present data from 41 wind turbines. In Fig. 1, they plot the turbine sound versus power. These 41 data points form two clumps based on power; one at about 700 kW and the second at about 2 MW. Regression lines fit to two measures of the power both show that the sound level is increasing at a rate of about 12 dB for a tenfold increase in power or about 3.6 dB per decade. Normalized spectra for these same two groups exhibit about a one-third of an octave decrease in the spectrum for the higher power relative to the lower power (Sec. D, Fig. 16). There is also a third much smaller clump of 4 turbines with power ratings of about 100 kW that are not used for much in the paper.

[5]A major effort was made to logically group the "symptoms" in Table I. It is possible that this grouping should have gone further and grouped "sleepiness, drowsiness, and sleep disturbance" with "fatigue and tiredness." That combined "symptom" would have resulted in 100% for the two categories that make up the table.

[6]Montavit (2014) states that 5%–10% of the population are "extremely sensitive" and that 5%–15% are "relatively insensitive." So 5%–10% of the population is probably closer to the percentage that we should be using rather than 15%.

[7]One of the reviewers questioned the use of A-weighted octave band levels. The authors also question this, but the IEC standard requires that the data be reported this way and the wind farm industry concurs.

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TOWN OF FOREST

PUBLIC COMMENTS FROM SENSITIVE RESIDENCES

IDENTIFIED IN EX.-FOREST-JUNKER-20

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Authorization for Use or Disclosure of Protected Health Information
(Required by the Health Insurance Portability and Accountability Act,
45 C.F.R. Parts 160 and 164)

I authorize the Town of Forest, through its legal representatives, to disclose a redacted copy of my provided medical information to the public record of the Public Service Commission of the State of Wisconsin.

I understand that the records I have voluntarily provided will have all sensitive information, to include my name, social security number, address, and any identifying information redacted, with the remainder submitted to the record of the Public Service Commission.

I understand that I have the right to revoke this authorization, at any time, in writing. I understand that I may revoke my authorization by submitting my written revocation to:
Oliveiera Law Group
22 East Mifflin, Suite 302
Madison, WI 53701
I understand that my revocation is not effective to the extent that another party, in reliance on this authorization, has already released records prior to receiving written notice of revocation.

By signing below, I hereby authorize the Town of Forest, by its legal representatives, to receive, redact, and submit my medical information into the record.

Dated this 9th day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

3116 Cty Rd Q
Clear Lake WI
54005
Address

[redacted]
3116 County Road Q
Clear Lake WI 54005

To Whom It May Concern:

My name is [redacted] and I currently reside at 3116 County Road Q, Clear Lake WI, township of Forest. I live with my significant other and our three children, [redacted]-age 9, [redacted]-age 8, and [redacted] age 2.

My hope is that you will listen to my concerns regarding the probable effects of the wind energy on our family's health and well-being, and act in favor of our concerns on the wind energy issue.

Our oldest son [redacted] suffers from mental health issues. Hypersensitivity to sound and sleep disturbance are two of his symptoms that are our main concerns, with the possibility of wind turbines coming in. The turbines would likely exacerbate these already prevalent symptoms. This would then lead to extreme irritability and loss of quality of life for him along with our entire family.

I also suffer from migraines. I have been hospitalized twice over the past few years. They are extremely painful, I lose my vision, and my limbs go numb. It is probable that turbines would amplify or increase my migraines. Again, my quality of life would be reduced due to these symptoms.

Again, please take this into consideration when making a decision that will impact my family. Act in our best interest.

Sincerely,

[redacted]

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Dated this 11 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

3136 Cty Rd. Q
Clear Lake Wis
54005
Address

[redacted]
Signature

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Dated this 11 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

3136 Cty. Rd. Q
Clear Lake, Wis
54005
Address

[redacted]
Signature

Health Issues April 11,2016

[redacted]>

Mon 4/11/2016 9:27 PM

[redacted] and I have lived in St Croix County, Forest township in Wisconsin for 75 years. We farm our land and are semi-retired and have health issues. [redacted] now has Heart Problems, Macular Degeneration, High Blood Pressure, Hypertension. I have headaches, High Blood Pressure, Hypertension and Sleep Disorder.We do not want to have more health issues do to Wind Turbine Noise and Shadow Flicker. As residents of Forest Township we deserve to have peaceful living conditions for the years we have left.

[redacted]

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By signing below, I hereby authorize the Town of Forest, by its legal representatives, to receive, redact, and submit my medical information into the record.

Dated this 12 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

2168 Cty Rd
Clear Lake Wi.
54005
Address

My name is [redacted]

I have lived on our 167 acre farm for over 46 years which is located in Forest township. St. Croix County, WI. We actively farm our property and spend much time outdoors as well as indoors.

I have suffered with migraines and high blood pressure for years. I have done my research and talked to people living in wind farms and know of many people who have told us that wind farms have caused them to suffer vertigo/dizziness, headaches, ear pain, stress, and sleep disturbance. I feel that my migraines and blood pressure problems will only increase living with the noise, vibrations, shadow flicker from wind turbines placed close to my farm.

[redacted]

4-12-16

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By signing below, I hereby authorize the Town of Forest, by its legal representatives, to receive, redact, and submit my medical information into the record.

Dated this 12th day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

2719 210th Ave
Deer Park WI 54007

[redacted]
Signature

Address

April 12, 2016

Updated Health Report:

My name is [redacted] and I reside at 2719 210th Ave Deer Park, WI 54007 along with my husband [redacted], Mother-in-Law [redacted], and my four children: [redacted], and [redacted]. We have been very concerned from the beginning regarding the Highland Wind Project due to the ongoing health concerns of myself and my children and this continues to be the case. I am concerned about how noise and light flicker would impact our health. My daughter [redacted] (17 years) suffers from migraine headaches and insomnia. [redacted] (13 years) has been diagnosed with Autism Spectrum Disorder and also ADHD. She is extremely sensitive to extra stimulus in her environment. [redacted] (9 years) has been diagnosed with epilepsy and ADHD. [redacted] started have epileptic seizures when he was four years old. He also has a lot of anxiety and I am extremely worried about how the added noise and light flicker might impact him. His seizures have been stable the last few years and I am concerned that a significant change in his environment could change that. I also have chronic migraines and know from my experiences driving in cars that light flicker can be a trigger for my migraines.

I believe that it is important that the health concerns of all of our residents are equally considered as we look at the impact of a project such as this.

Respectfully,

[redacted]

MEDICAL RELEASE AUTHORIZATION FORM

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I understand that I have the right to revoke this authorization, at any time, in writing. I understand that I may revoke my authorization by submitting my written revocation to:
Oliveiera Law Group
22 East Mifflin, Suite 302
Madison, WI 53701
I understand that my revocation is not effective to the extent that another party, in reliance on this authorization, has already released records prior to receiving written notice of revocation.

By signing below, I hereby authorize the Town of Forest, by its legal representatives, to receive, redact, and submit my medical information into the record.

Dated this 11th day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

2168 Cty Rd P
Clear Lake,
Wisconsin
Address 54005

My name is [redacted]

I have lived on our 167 acre farm for over 46 years which is located in Forest township, St. Croix County, WI. We actively farm our property and spend much time outdoors as well as indoors.

I have suffered with Vertigo for years. I can't imagine living next to wind turbines with the noise, vibrations, shadow flicker which will make my health conditions even worse. Wind turbines have caused people to get vertigo/dizziness, headaches,ear pain and sleep disturbance.

My health problems have increased since I first gave my public input in Forest and at the PSC. I have heart valve issues and and a extra heart beat. My husband has suffered for years with migraines and high blood pressure. I also work selling real estate. Our lives are very busy and we need our sleep, we need quiet, and we do not need shadow flicker over our farm.

4-11-2016

[redacted]

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Dated this 12 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

3162 State Road 64
Glenwood City
WI. 54013-4707
Address

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Dated this 12 day of April, 2016, in the County of ST Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

3162 ST. RD 64
Glenwood City
Wis 54013
Address

April 12, 2016

[redacted]
3162 State Road 64
Glenwood City, WI 54013

My wife and I have lived in the town of Forest for more than 40 years. The health issues at our home have remained relatively steady, except my wife's sensitivity to motion and light has increased. She still has diabetes and chronic lymphocytic leukemia (CLL). Her hearing has decreased and she needs hearing aids. We need some modicum of protection that a 40 dBA noise limit would offer at night.

One of our sons also live in the town of Forest and is raising a family. I have concern should the Highland Wind turbine come in, it may affect his health, the health of his wife, and his children, who need a good night's sleep to do well in school. I have a neighbor whose son is diagnosed with Asperger's syndrome. I have other neighbors that have health issues like heart conditions, tinnitus, migraines, and hearing problems. These people also deserve some protection that maybe 40 dBA noise limits at night would offer.

[redacted]

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Dated this 9 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

2920 Hwy 64
Glenwood City
Wisconsin 54013
Address

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Dated this 9 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

2920 Hwy 64
Glenwood City,
Wisconsin 54013
Address

[redacted] and [redacted]
2920 Hwy. 64 Glenwood City, WI 54013

I ([redacted]) am writting this letter in regards to some major health issues in our life.

[redacted] and I sold our dairy farm at 2948 Hwy. 64 to our son and daughter-in-law and moved a double wide house down the road about 1/4 mile (still on our land) to 2920 Hwy. 64 where we now live. This move has us even closer yet to more turbines.

With [redacted] parkinsons and sleep REM disorder that are continuous, the noise and flicker of lights from the turbines will worsen his health conditions. Right now he has a very hard time getting a good nights sleep even with the sleeping pills that he has been prescribed. He experiences many nights of disruptive sleep. Then during the day he has to sleep alot because he is just to tired from the sleepless night ~~the night~~ the night before. It is just a vicious cycle... If this sleeplessnes goes on for a couple days in a row then his Parkenson's

starts really acting up with shuffling of his feet losing his balance and almost tripping
[redacted] also has high blood pressure, anxiety attacks and deals with depression.

And then when he has a hard time sleeping, I don't get much sleep at all because of [redacted] agitation. This causes my ostoarthritis to flare up and becomes more painful, because my body has not gotten the rest I need to start a new day.

I also get very dizzy, light headed, vertigo and motion sickness that can put me down flat in bed some days.

I know we are not the only family in Forest township with health issues, and what about our precious little ones....

Would you please consider all these issues?...

April 9, 2016

[redacted]

[redacted]

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Dated this 9th day of April, 2016, in the County of St Croix, State of Wisconsin.

[redacted]
Full Name

3174-205th Ave
Glenwood City, WI
54013
Address

[redacted]
Signature

[redacted]

3174-205th Ave

Glenwood City, Wi. 54013

10 April 2016

[redacted]

St Paul, Mn

We have owned our farm for 38 years. Because of our family health issues, the proposed wind turbine farm is of great concern to us.

I have had two (2) heart attacks that resulted in damage to my heart + reduced its functioning by one-third. Since 2012 I have developed attrial fibulation. The strong medicine I take largly controls it, but has resulted in having a defibulator implanted in Oct 2014.

Unfortunatly, I also have central sleep apnea that requires a C-pap machine when I sleep (2013)

My macular degeneration makes me very light sensitive, & espically to light change when sleeping

These health issues, combined with hearing loss have resulted in moderate to severe headaches.

Several years ago our daughter was in a car accident (hit by a drunk & unlicensed driver). She suffered severe neck & head soft tissue damage. The resultant headaches very severe & disabling. She is unable to work. She is hyper sensitive to sound/noise. Extensive medical care has provided limited help. Visits to our farm are greatly enjoyed by her & she looks forward to the peace & quiet of the country

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By signing below, I hereby authorize the Town of Forest, by its legal representatives, to receive, redact, and submit my medical information into the record.

Dated this 9 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

2948 Hwy 64
Glenwood City, WI
54013
Address

[redacted]
2948 Hwy. 64
Glenwood City, WI 54013

Family Members: [redacted] 32, [redacted] 30, [redacted], [redacted] 3 & [redacted] 9 Months

My name is [redacted]. I am a resident of the Town of Forest. I have concerns about my health issues and the possible negative side effects the Turbines could have on my health.

I was diagnosed with a seizure disorder 5 years ago. I am on medication for this disorder. Seizures are unpredictable. This disorder makes me more susceptible to having seizures. My seizure disorder also enhances motion sickness symptoms. Both significant noise and light exposure causes me to have headaches and flu like symptoms. I have also been diagnosed with anxiety and depression which is currently controlled also by medication.

My disorder is currently very well controlled and I have a very good quality of life. I sleep well at night; I have a very good appetite, very few visits to the doctor except for my annual check-ups for my conditions. I know to stay away from things that could enhance any of those symptoms.

I have three small children and am currently a stay at home mom and part time Massage Therapist. My children depend on my every day to care for them and I am concerned about the unknown negative effects the wind turbines could have on my health and also the health of my family.

Having a seizure not only causes other negative health effects, but takes part of my livelihood also by having your driver's license suspended for three months after an episode and if you have another episode within three months of the initial seizure, they suspend it for another three months. The thought of not being able to do my normal daily activities by way of getting around for everyday errands, job, and appointments is something I do not even want to think about. There are no studies about how turbines affect individuals with seizure disorders.

There are still so many unknown health effects from Industrial Wind Turbines. It's very scary to think my conditions could flare up and very negatively affect the very good quality of life I currently have.

I really hope you would find it extremely important to take a look at my health conditions as well as others in our township, which I am aware there are many more than 17. Everyone not only needs to be treated equal by not only Emerging Energies but the PSC also, who is there to protect the people of Wisconsin from having their quality of life negatively impacted.

I thank you for your time and hope you now take the time to look at not only the 17 residents of Forest who have already shared their medical conditions, but the residents who have not or are afraid to speak out about their health issues who could also be negatively impacted by Industrial sized wind turbines.

Sincerely,

[redacted]

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Dated this 9 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

2953 210th Ave.
Emerald, Wi

Address

[redacted]
2953 210th Avenue
Emerald, Wi. 54013

At our home, we would be surrounded by 12 turbines within a mile of our property based on the proposed siting plan for the Highland Wind project. The closest one would be less than a quarter mile away. Should the PSC allow Highland Wind to be built regardless of the health and safety of the residents of Forest, I believe it will impact the health of me and my husband, and based on my research and discussions with people who have lived within other wind projects, it will impact our neighbors as well.

I was diagnosed with high blood pressure 3-4 years ago and am currently on medication to control it. I also deal with clinical depression and am on medication for that as well. I have a tendency towards headaches and based on my experiences when I have been in close proximity to a wind project, believe that the infrasound created by industrial wind turbines will potentially affect me. I would hope, but don't know that I would still be capable of working from my home office as headaches could affect that aspect of my life as well.

[redacted] has some age related hearing loss and there would be concerns that it could increase and that other hearing related issues (tinnitus) could become an issue. [redacted] is a cancer survivor and while wind turbines themselves don't cause cancer, other factors related to wind turbines and the stress of living within a 44 turbine industrial wind project, is not a healthy environment to live in.

I also have several neighbors who suffer from motion sickness. While only one submitted an affidavit to that fact, all residents should be considered for protective measures. There are several families with children who have health issues, one family on 210th Avenue has a child who is epileptic. There are also children who are autistic in the vicinity. There are peer reviewed studies, including one from NASA from the early 80's or 90's that identified issues with infrasound and low frequency noise. The decision should not be based on a report by the Wind Siting Council who not only have a pro-wind majority, but members of the council that would benefit financially by approving the Highland Wind Project.

The PSC members should not be discriminatory in protecting the health and safety of Wisconsin residents. After all, it is the PUBLIC Service Commission and not the WIND service commission.

[redacted]
Town of Forest Resident
Affidavit submitted on Docket 2535-CE-100

[redacted]

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Dated this 9 day of April, 2016, in the County of ST. CROIX, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

1892 Co Rd
Emerald
Wis 54012
Address

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Dated this 9 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

1892 Co. Rd D
Glenwood City, WI
54013
Address

[redacted]
1892 Co. Rd D
Glenwood City, WI 54013

We are concerned about how the turbines will affect our health issues. [redacted] has sleep apnea and struggles routinely with not sleeping well at night. He is on medication for high blood pressure and heart arrhythmia. He has a pacemaker/defibrillator implant which has recently been replaced. [redacted] has hearing loss and has experienced dizziness during the day.

We are aware of numerous neighbors who have sleep apnea issues or experience migraine headaches. We feel it is unfair to them to not be considered in this survey when their welfare is in jeopardy.

Respectfully,

[redacted]

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Dated this 9th day of April, 2016, in the County of St Croix State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

1969 County Road P
Glenwood City WI
54013
Address

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By signing below, I hereby authorize the Town of Forest, by its legal representatives, to receive, redact, and submit my medical information into the record.

Dated this 10 day of April, 2016, in the County of St. Croix, State of Wisconsin.

[redacted]
Full Name

[redacted]
Signature

1969 County Road P
Glenwood City, WI
54013
Address

Wisconsin Public Service Commission

My name is [redacted] and my address is 1969 County Road P, Glenwood City WI, 54013. I am writing this in regards to the sensitive residence items currently under review for the Highland Wind Farm LLC in the town of Forest Wisconsin. My wife and I have lived in the Town of Forest since 1991.

First off I would like to review and update a prior survey that was submitted back in the fall of 2012. Our household consists of myself, my wife [redacted] and my daughters, [redacted] [redacted] and [redacted] There were two items noted in the previous survey, our daughter's asthma and [redacted] irregular heartbeat. [redacted] irregular heartbeat is of most concern. One item that I neglected to document on the previous form is the fact that one of my daughters is also prone to head aches. All of these still exist today. Since that document was submitted, I have also had some issues with hearing loss and my wife has recently had bouts of vertigo.

With these being noted, I have concerns about how the audible and inaudible noise and pressure waves will affect my family. I know from experience and a visit to the Shirley wind farm on how this affected my daughter, I did not tell her where we were going and within 5 minutes of being near the turbines, she was complaining of headaches and wanted to get away from there. They went away after we were no longer near the wind farm. I have a huge concern for my wife, with her vertigo and irregular heartbeat. How will the shadow flicker and pressure waves affect her? When she has one of these spells, she needs to stop what she is doing and find somewhere where there is no auditory or visual stimulus until it passes. One of the items that have triggered her vertigo is movement around her. I also have friends and family that are prone to seizures and have a pacemaker. Will they be able to visit and not have any health affects due to the wind farm?

Now, my question to the PSC, how were the 6 sensitive residents identified during the approval process? Why were 6 taken into consideration and the other 11 not? My family is one that was not. Was there medical professionals involved in the decision making process? There are many concerns on how this was handled. I feel that things should be looked at fairly and that all 17 families that submitted health forms should have been treated with the same respect.The town of Forest did their due diligence in working with the residents to gather this information. It would have made much more sense for the developer to find this information out prior to siting the turbines. If they are to be good stewards and neighbors, why was this not completed prior to the application? I feel for any resident that this has the potential to affect.

Thank you for taking this into consideration.

[redacted]

[redacted]

4-10-16